Chapter 3 - Flow Control Design

Note: Figures in Chapter 3 courtesy of King County, except as noted

This chapter presents methods, criteria, and details for hydraulic analysis and design of flow control facilities and roof downspout controls. *Flow control facilities* are detention or infiltration facilities engineered to meet the flow control standards specified in Volume I. *Roof downspout controls* are infiltration or dispersion systems for use in individual lots, proposed plats, and short plats. Roof downspout~~s~~ controls are ~~may be~~ used in conjunction with, and in addition to, any flow control facilities that may be necessary. Implementation of roof downspout controls may reduce the total effective impervious area and result in less runoff from these surfaces. Ecology's Hydrology Model incorporates flow credits for implementing two types of roof downspout controls. These are:

- If roof runoff is ***infiltrated*** according to the requirements of this section, the roof area may be discounted from the total project area used for sizing ~~the~~ stormwater~~flow control~~ facilit~~y~~ies ~~as required in Volume I~~. This is done by clicking on the "Credit" button in the WWHM and entering the percent of roof area that is being infiltrated.
- If roof runoff is ***dispersed*** ~~using a dispersion trench designed~~ according to the requirements of this section on single-family lots greater than 22,000 square feet, and the *vegetative flow*[*] path ~~of the roof runoff~~ is 50 feet or larger through undisturbed native landscape or lawn/landscape area that meets BMP T5.13, the roof area may be modeled as grassed surface. This is done by clicking on the "Credits" button in the WWHM and entering the percent of roof area that is being dispersed.

This chapter also provides a description of the use of infiltration facilities for flow control. Additional design considerations and general limitations of the infiltration facilities and small site BMPs are covered in Volume V.

Roof downspout controls and small site BMPs should be applied to individual commercial lot developments when the percent impervious area and pollutant characteristics are comparable to those from residential lots.

3.1 Roof Downspout Controls

This section presents the criteria for design and implementation of roof downspout controls. *Roof downspout controls* are simple pre-engineered designs for infiltrating and/or dispersing runoff from roof areas for the

[*] *Vegetative flow* path is measured from the downspout or dispersion system discharge point to the downstream property line, stream, wetland, or other impervious surface.

purposes of increasing opportunities for groundwater recharge and reduction of runoff volumes from new developments.

Selection of Roof Downspout Controls

Large lots in rural areas (5 acres or greater) typically have enough area to disperse or infiltrate roof runoff. Lots created in urban areas will typically be smaller (about 8,000 square feet) and have a limited amount of area in which to site infiltration or dispersion trenches. Downspout infiltration should be used in those soils that readily infiltrate (coarse sands and cobbles to medium sands). Dispersion BMPs should be used for urban lots located in less permeable soils, where if infiltration is not feasible. Where dispersion is not feasible because of very small lot size, or where there is a potential for creating drainage problems on adjacent lots, downspouts should be connected to the street storm drain system, which directs the runoff to a ~~regional~~ stormwater management facility.

Where roof downspout controls are planned, the following three types must be considered in descending order of preference:

- Downspout infiltration systems (Section 3.1.1)
- Downspout dispersion systems (Section 3.1.2)
- Downspout perforated stub-out connections (Section 3.1.3)

Figure 3.1 illustrates, in general, how roof downspout controls are selected and applied in single-family subdivision projects. However, local jurisdictions may adopt approaches that are more specific to their locality. Where supported by appropriate soil infiltration tests, downspout infiltration in finer soils may be practical using a larger infiltration system.

Note: Other innovative downspout control BMPs such as rain barrels, ornamental ponds, downspout cisterns, or other downspout water storage devices may also be used if approved by the reviewing authority.

Roof Downspout Controls in Potential Landslide Hazard Areas

If or where local governments have identified "geologically hazardous areas" (WAC 365-195-410), we recommend that lots immediately adjacent to the hazard area collect roof runoff in a tightline system which conveys the runoff to the base of the slope.

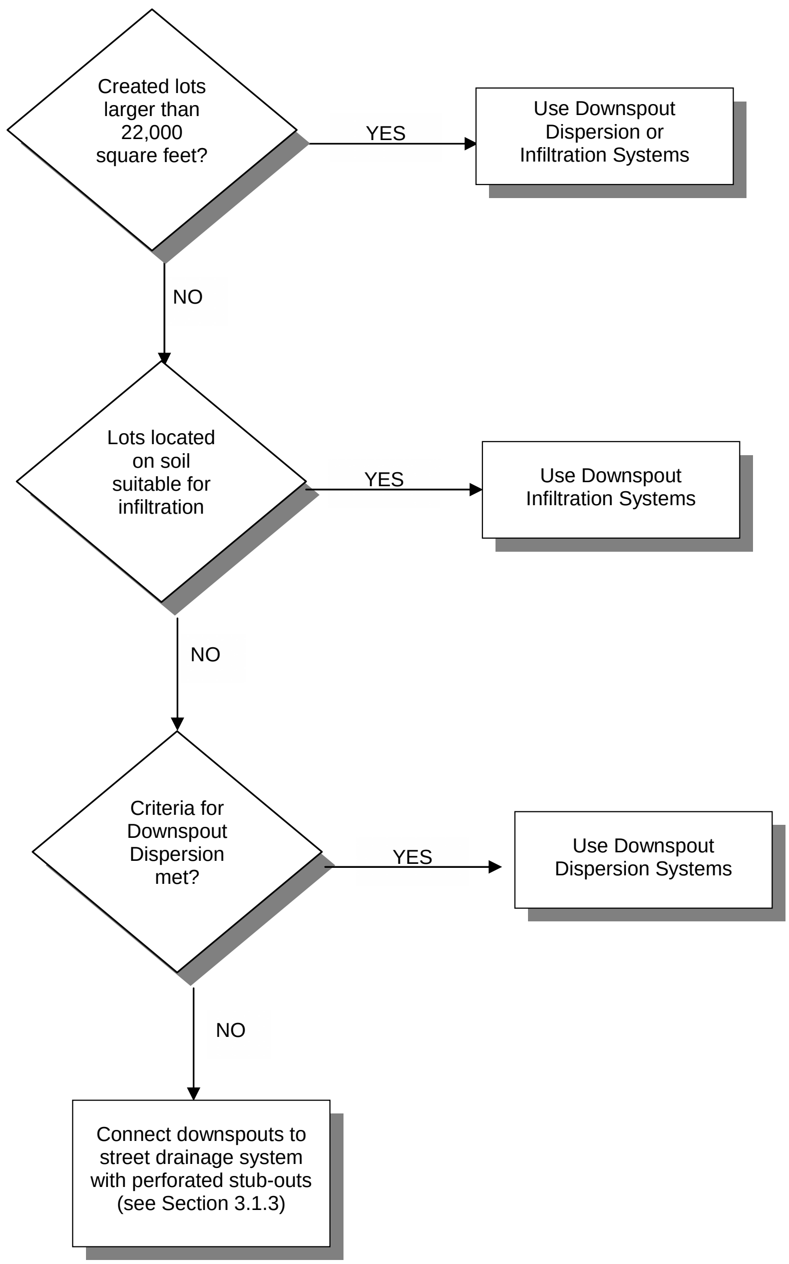


Figure 3.1 Flow Diagram Showing Selection of Roof Downspout Controls

3.1.1 Downspout Infiltration Systems

Downspout infiltration systems are trench or drywell designs intended only for use in infiltrating runoff from roof downspout drains. They are not designed to directly infiltrate runoff from pollutant-generating impervious surfaces.

Application

The following apply to parcels as described in Volume I:

1. Single family subdivision projects subject to Minimum Requirement #7 for flow control (Volume I) must provide for individual downspout infiltration systems on all lots smaller than 22,000 square feet if feasible. Local governments may specify a different lot size that is more appropriate **-** based on local soil and slope conditions and rainfall. Concentrated flows may not be directed to adjoining lots. They must be dispersed and retained on the building lot to the maximum extent possible.
2. The feasibility or applicability of downspout infiltration must be evaluated for all subdivision single-family lots smaller than 22,000 square feet. The evaluation procedure detailed below must be used to determine if downspout infiltration is feasible or whether downspout dispersion can be used in lieu of infiltration.
3. For subdivision single-family lots greater than or equal to 22,000 square feet, downspout infiltration is optional, and the evaluation procedure detailed below may be used if downspout infiltration is being proposed voluntarily.
4. If site-specific tests indicate less than 3 feet of permeable soil from the proposed final grade to the seasonal high groundwater table, then a downspout dispersion system per Section 3.1.2 may be used in lieu of infiltration.
5. On lots or sites with more than 3 feet of permeable soil from the proposed final grade to the seasonal high groundwater table, downspout infiltration is considered feasible if the soils are outwash type soils and the infiltration trench can be designed to meet the minimum design criteria specified below.

Note: If downspout infiltration is not provided on these lots, then a downspout dispersion system must be provided per Section 3.1.2.

Flow Credit for Roof Downspout Infiltration

If roof runoff is infiltrated according to the requirements of this section, the roof area may be discounted from the project area used for sizing ~~the~~stormwater~~ flow control~~ facilitiesy~~ as required in Volume I, Minimum Requirement #7~~. This is done by clicking on the “Credit” button in WWHM and entering the percent of roof area that is being infiltrated.

Procedure for Evaluating Feasibility

1. A soils report must be prepared by a locally licensed onsite sewage designer or by other suitably trained persons working under the supervision of a professional engineer, geologist, hydrogeologist, or engineering geologist registered in the State of Washington to determine if soils suitable for infiltration are present on the site. The report must reference a sufficient number of soils logs to establish the type and limits of soils on the project site. The report should at a minimum identify the limits of any *outwash type soils* (i.e., those meeting USDA soil texture classes ranging from coarse sand and cobbles to medium sand) versus other soil types and include an inventory of topsoil depth.
2. On lots or sites with no outwash type soils, a downspout dispersion system per Section 3.1.2 may be used in lieu of infiltration.
3. On lots or sites containing outwash type soils (coarse sand and cobbles to medium sand), additional site-specific testing must be done. Individual lot or site tests must consist of at least one soils log at the location of the infiltration system, a minimum of 4 feet in depth (from proposed grade), identifying the SCS series of the soil and the USDA textural class of the soil horizon through the depth of the log, and noting any evidence of high groundwater level, such as mottling.

   Note: This testing must also be carried out on lots or sites where downspout infiltration is being proposed in soils other than outwash.
4. If site-specific tests indicate less than 3 feet of permeable soil from the proposed final grade to the seasonal high groundwater table, then a downspout dispersion system per Section 3.1.2 may be used in lieu of infiltration.
5. On lots or sites with more than 3 feet of permeable soil from the proposed final grade to the seasonal high groundwater table, downspout infiltration is considered feasible if the soils are outwash type soils and the infiltration trench can be designed to meet the minimum design criteria specified below.

Design Criteria for Infiltration Trenches

Figure 3.2 shows a typical downspout infiltration trench system, and Figure 3.3 presents an alternative infiltration trench system for sites with coarse sand and cobble soils. These systems are designed as specified below.

General

1. The following minimum lengths (linear feet) per 1,000 square feet of roof area based on soil type may be used for sizing downspout infiltration trenches.

Coarse sands and cobbles	20 LF
Medium sand	30 LF
Fine sand, loamy sand	75 LF

Sandy loam	125 LF
Loam	190 LF

2. Maximum length of trench must not exceed 100 feet from the inlet sump.
3. Minimum spacing between trench centerlines must be 6 feet.
4. Filter fabric must be placed over the drain rock as shown on Figure 3.2 prior to backfilling.
5. Infiltration trenches may be placed in fill material if the fill is placed and compacted under the direct supervision of a geotechnical engineer or professional civil engineer with geotechnical expertise, and if the measured infiltration rate is at least 8 inches per hour. Trench length in fill must be 60 linear feet per 1,000 square feet of roof area. Infiltration rates can be tested using the methods described in Section 3.3.
6. Infiltration trenches should not be built on slopes steeper than 25 percent (4:1). A geotechnical analysis and report may be required on slopes over 15 percent or if located within 200 feet of the top of steep slope or landslide hazard area.
7. Trenches may be located under pavement if a small yard drain or catch basin with grate cover is placed at the end of the trench pipe such that overflow would occur out of the catch basin at an elevation at least one foot below that of the pavement, and in a location which can accommodate the overflow without creating a significant adverse impact to downhill properties or drainage systems. This is intended to prevent saturation of the pavement in the event of system failure.

Design Criteria for Infiltration Drywells

Figure 3.4 shows a typical downspout infiltration drywell system. These systems are designed as specified below.

General

1. Drywell bottoms must be a minimum of 1 foot above seasonal high groundwater level or impermeable soil layers.
2. If using drywells, each drywell may serve up to 1000 square feet of impervious surface for either medium sands or coarse sands.
3. Typically drywells are 48 inches in diameter (minimum) and have a depth of 5 feet (4 feet of gravel and 1 foot of suitable cover material).
4. Filter fabric (geotextile) must be placed on top of the drain rock and on trench or drywell sides prior to backfilling.
5. Spacing between drywells must be a minimum of 4 feet.
6. Downspout infiltration drywells must not be built on slopes greater than 25% (4:1). Drywells may not be placed on or above a landslide hazard area or slopes greater than 15% without evaluation by a

professional engineer with geotechnical expertise or a licensed ~~qualified~~ geologist, hydrogeologist, or engineering geologist, and with jurisdiction approval.

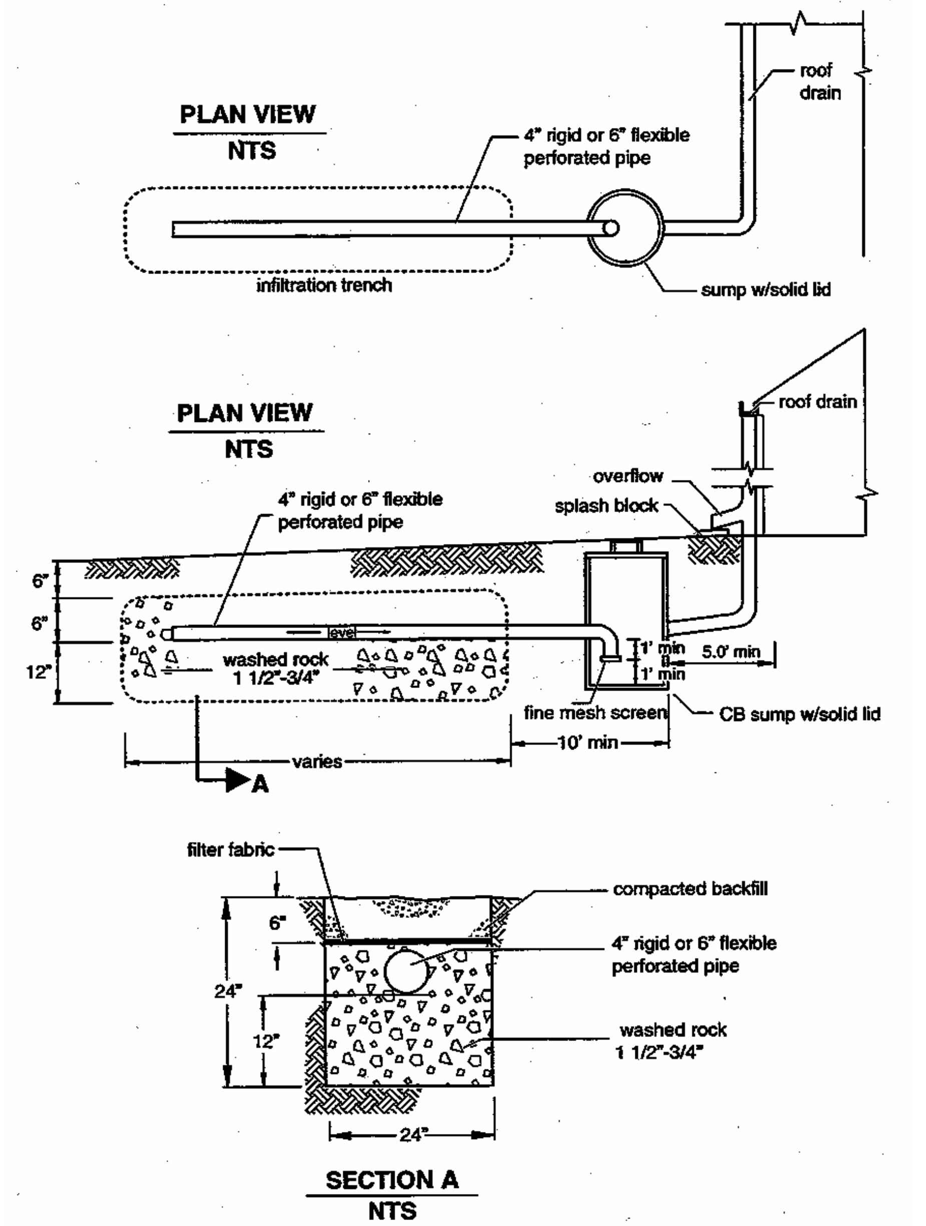


Figure 3.2 Typical Downspout Infiltration Trench

Source: King County

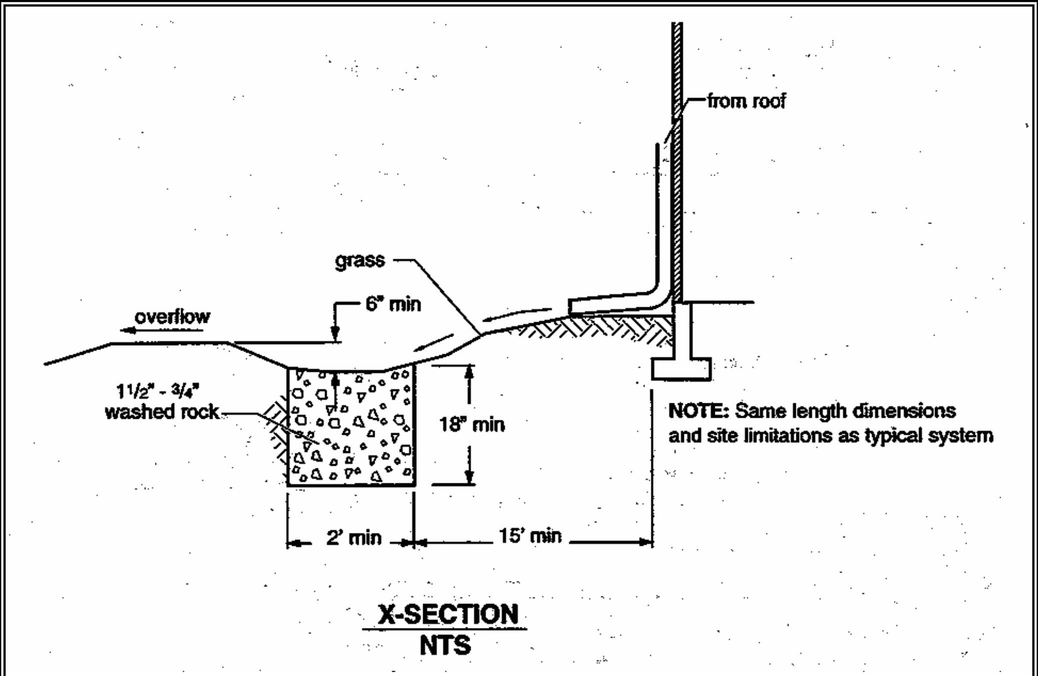


Figure 3.3 Alternative Downspout Infiltration Trench System For Coarse Sand And Gravel

Source: King County

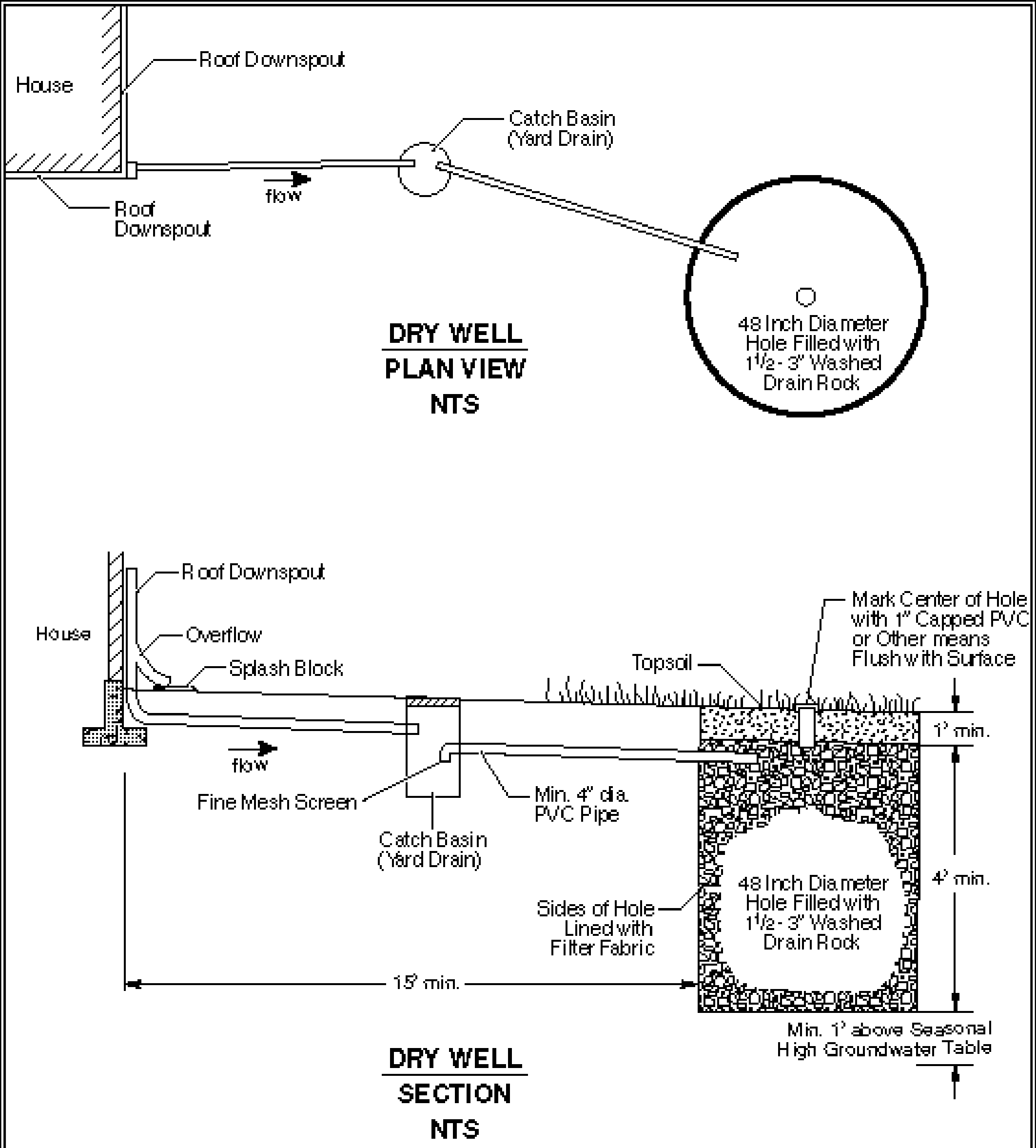


Figure 3.4 Typical Downspout Infiltration Drywell

Setbacks

Local governments may require specific setbacks in sites with steep slopes, land slide areas, open water features, springs, wells, and septic tank drain fields. Adequate room for maintenance access and equipment should also be considered. Examples of setbacks commonly used include the following:

1. All infiltration systems should be at least 10 feet from any structure, property line, or sensitive area (except steep slopes).
2. All infiltration systems must be at least 50 feet from the top of any sensitive area steep slope. This setback may be reduced to 15 feet based on a geotechnical evaluation, but in no instances may it be less than the buffer width.
3. For sites with septic systems, infiltration systems must be downgradient of the drainfield unless the site topography clearly prohibits subsurface flows from intersecting the drainfield.

3.1.2 Downspout Dispersion Systems

Downspout dispersion systems are splash blocks or gravel-filled trenches, which serve to spread roof runoff over vegetated pervious areas. Dispersion attenuates peak flows by slowing entry of the runoff into the conveyance system, allows for some infiltration, and provides some water quality benefits.

Application

Downspout dispersion must be used in all subdivision single-family lots, which meet one of the following criteria:

1. Lots greater than or equal to 22,000 square feet where downspout infiltration is not being provided according to the requirements in Section 3.1.1.

2. Lots smaller than 22,000 square feet where soils are not suitable for downspout infiltration (as determined in Section 3.1.1) and where the design criteria below can be met.

Flow Credit for Roof Downspout Dispersion

If roof runoff is dispersed ~~using a dispersion trench designed~~ according to the requirements of this section on single-family lots greater than 22,000 square feet, and the *vegetative flow** path ~~of the roof runoff~~ is 50 feet or larger through undisturbed native landscape or lawn/landscape area that meets BMP T5.13, the roof area may be modeled as grassed surface. This is done by clicking on the “Credits” button in the WWHM and entering the percent of roof area that is being dispersed.

* *Vegetative flow* path is measured from the downspout or dispersion system discharge point to the downstream property line, stream, wetland, or other impervious surface.

Design Criteria

1. Downspout trenches designed as shown in Figure 3.5 should be used for all downspout dispersion applications except where splash blocks are allowed below.
2. Splash blocks shown in Figure 3.7 may be used for downspouts discharging to a *vegetated flowpath* at least 50 feet in length as measured from the downspout to the downstream property line, structure, steep slope, stream, wetland, or other impervious surface. Sensitive area buffers may count toward flowpath lengths.
3. If the vegetated flowpath (measured as defined above) is less than 25 feet on a subdivision single family lot, a perforated stub-out connection per Section 3.1.3 may be used in lieu of downspout dispersion. A perforated stub-out may also be used where implementation of downspout dispersion might cause erosion or flooding problems, either on site or on adjacent lots. This provision might be appropriate, for example, for lots constructed on steep hills where downspout discharge could be cumulative and might pose a potential hazard for lower lying lots, or where dispersed flows could create problems for adjacent offsite lots. Perforated stub-outs are not appropriate when seasonal water table is <1 foot below trench bottom.
4. For sites with septic systems, the discharge point of all dispersion systems must be downgradient of the drainfield. This requirement may be waived if site topography clearly prohibits flows from intersecting the drainfield.

Design Criteria for Dispersion Trenches

1. A vegetated flowpath of at least 25 feet in length must be maintained between the outlet of the trench and any property line, structure, stream, wetland, or impervious surface. A vegetated flowpath of at least 50 feet in length must be maintained between the outlet of the trench and any steep slope. Sensitive area buffers may count towards flowpath lengths.
2. Trenches serving up to 700 square feet of roof area may be simple 10-foot-long by 2-foot wide gravel filled trenches as shown in Figure 3.5. For roof areas larger than 700 square feet, a dispersion trench with notched grade board as shown in Figure 3.6 may be used as approved by the local jurisdiction. The total length of this design must not exceed 50 feet and must provide at least 10 feet of trench per 700 square feet of roof area.
3. A setback of at least 5 feet should be maintained between any edge of the trench and any structure or property line.
4. No erosion or flooding of downstream properties may result.

5. Runoff discharged towards landslide hazard areas must be evaluated by a geotechnical engineer or a ~~qualified~~ licensed geologist, hydrogeologist, or engineering geologist. The discharge point may not be placed on or above slopes greater than 20% or above erosion hazard areas without evaluation by a geotechnical engineer or qualified geologist and jurisdiction approval.

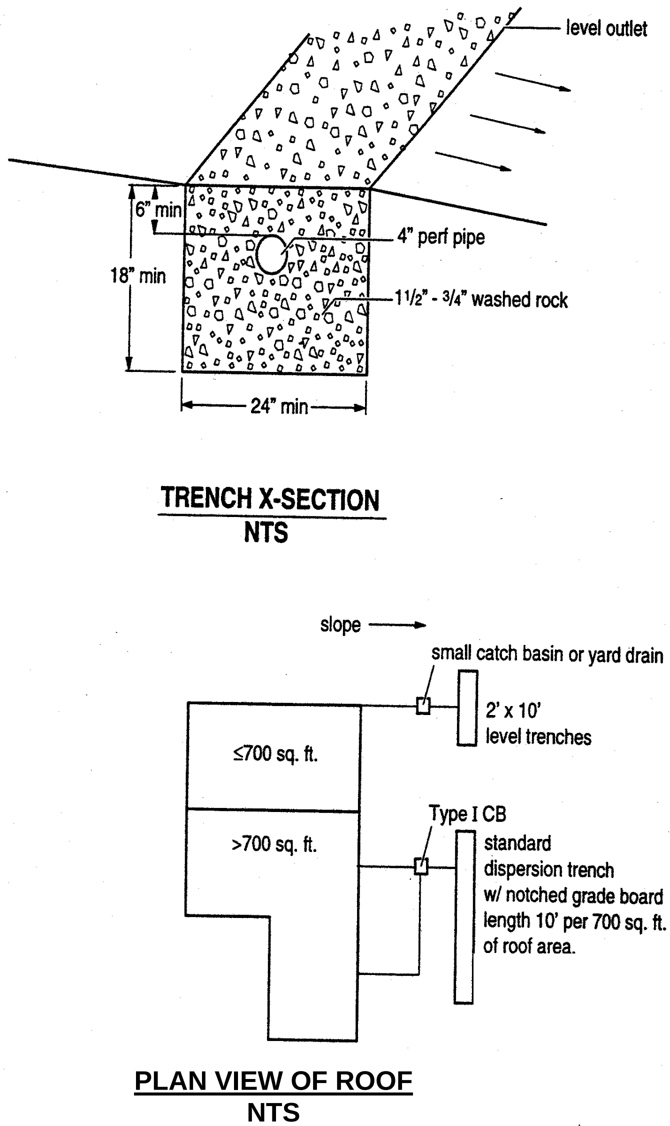


Figure 3.5 Typical Downspout Dispersion Trench

Source: King County

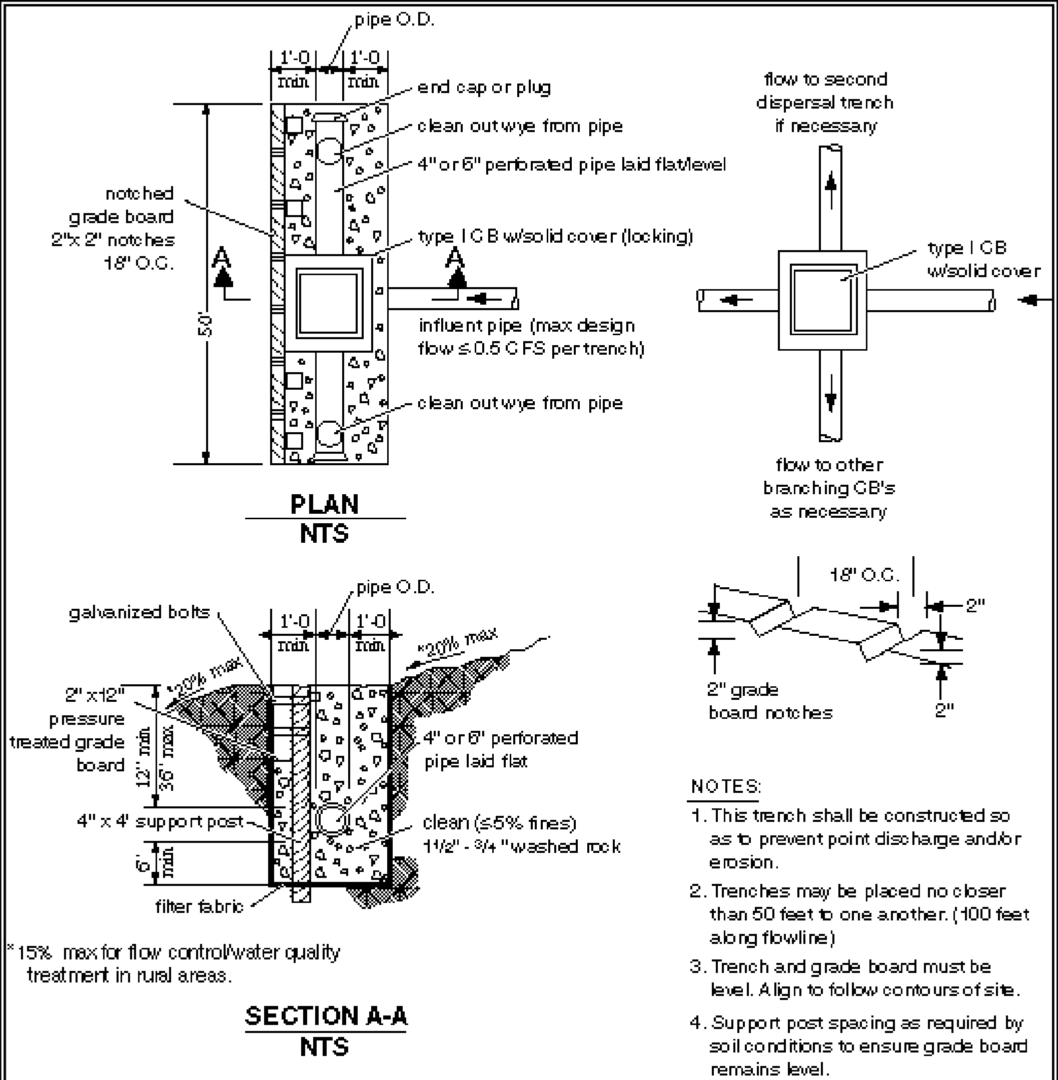


Figure 3.6 Standard Dispersion Trench with Notched Grade Board

Design Criteria for Splashblocks

A typical downspout splashblock is shown in Figure 3.7. In general, if the ground is sloped away from the foundation and there is adequate vegetation and area for effective dispersion, splashblocks will adequately disperse storm runoff. If the ground is fairly level, if the structure includes a basement, or if foundation drains are proposed, splashblocks with downspout extensions may be a better choice because the discharge point is moved away from the foundation. Downspout extensions can include piping to a splashblock/discharge point a considerable distance from the downspout, as long as the runoff can travel through a well-vegetated area as described below.

The following apply to the use of splashblocks:

1. A vegetated flowpath of at least 50 feet should be maintained between the discharge point and any property line, structure, steep slope, stream, wetland, lake, or other impervious surface. Sensitive area buffers may count toward flowpath lengths.
2. A maximum of 700 square feet of roof area may drain to each splashblock.
3. A splashblock or a pad of crushed rock (2 feet wide by 3 feet long by 6 inches deep) should be placed at each downspout discharge point.
4. No erosion or flooding of downstream properties may result.
5. Runoff discharged towards landslide hazard areas must be evaluated by a professional engineer with geotechnical expertise or a qualified geologist. Splashblocks may not be placed on or above slopes greater than 20% or above erosion hazard areas without evaluation by a professional engineer with geotechnical expertise or ~~qualified~~ a licensed geologist, hydrogeologist, or engineering geologist, and jurisdiction approval.
6. For sites with septic systems, the discharge point must be downslope of the primary and reserve drainfield areas. This requirement may be waived if site topography clearly prohibits flows from intersecting the drainfield or where site conditions (soil permeability, distance between systems, etc) indicate that this is unnecessary.

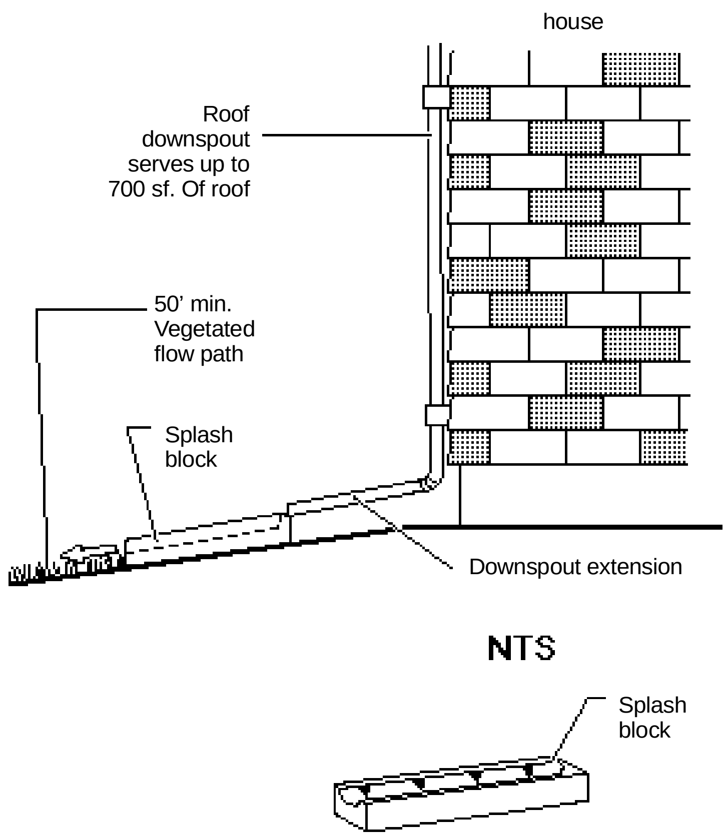


Figure 3.7 Typical Downspout Splashblock Dispersion

3.1.3 Perforated Stub-Out Connections

A perforated stub-out connection is a length of perforated pipe within a gravel-filled trench that is placed between roof downspouts and a stub-out to the local drainage system. Figure 3.8 illustrates a perforated stub-out connection. These systems are intended to provide some infiltration during drier months. During the wet winter months, they may provide little or no flow control. Perforated stub-outs are not appropriate when seasonal water table is < 1 foot below trench bottom.

In single-family subdivision projects subject to Minimum Requirement #7 for flow control (see Volume I), perforated stub-out connections may be used only when downspout infiltration or dispersion is not feasible per the criteria in Sections 3.1.1 and 3.1.2.

Location of the connection should be selected to allow a maximum amount of runoff to infiltrate into the ground (ideally a dry location on the site that is relatively well drained). To facilitate maintenance, the perforated pipe portion of the system should not be located under impervious or heavily compacted (e.g., driveways and parking areas) surfaces.

Perforated stub-out connections should consist of at least 10 feet of perforated pipe per 5,000 square feet of roof area laid in a level, 2-foot wide trench backfilled with washed drain rock. The drain rock should extend to a depth of at least 8 inches below the bottom of the pipe and should cover the pipe. The pipe should be laid level and the rock trench covered with filter fabric and 6 inches of fill (see Figure 3.8).

Setbacks are the same as for infiltration trenches.

Potential runoff discharge towards a landslide hazard area must be evaluated by a professional engineer with geotechnical expertise or a ~~qualified~~licensed geologist, hydrogeologist, or engineering geologist**.** The perforated portion of the pipe may not be placed on or above slopes greater than 20% or above erosion hazard areas without evaluation by a professional engineer with geotechnical expertise or qualified geologist and jurisdiction approval.

For sites with septic systems, the perforated portion of the pipe must be downgradient of the drainfield primary and reserve areas. This requirement can be waived if site topography will clearly prohibit flows from intersecting the drainfield or where site conditions (soil permeability, distance between systems, etc) indicate that this is unnecessary.

Methods of Analysis **Detention Volume and Outflow.** The volume and outflow design for detention ponds must be in accordance with Minimum Requirements #7 in Volume I and the hydrologic analysis and design methods in Chapter 1 of this Volume. Design guidelines for restrictor orifice structures are given in Section 3.2.4.

Note: The design water surface elevation is the highest elevation which occurs in order to meet the required outflow performance for the pond.

Detention Ponds in Infiltrative Soils. Detention ponds may occasionally be sited on till soils that are sufficiently permeable for a properly functioning infiltration system (see Section 3.3). These detention ponds have a surface discharge and may also utilize infiltration as a second pond outflow. Detention ponds sized with infiltration as a second outflow must meet all the requirements of Section 3.3 for infiltration ponds, including a soils report, testing, groundwater protection, pre-settling, and construction techniques.

Emergency Overflow Spillway Capacity. For impoundments under 10-acre-feet, the emergency overflow spillway weir section must be designed to pass the 100-year runoff event for developed conditions assuming a broad-crested weir. The **broad-crested weir equation** for the spillway section in Figure 3.13, for example, would be:

$$Q_{100} = C\,(2g)^{1/2}\left[\frac{2}{3}LH^{3/2} + \frac{8}{15}(\operatorname{Tan}\theta)\,H^{5/2}\right] \qquad \text{(equation 1)}$$

Where Q_{100} = peak flow for the 100-year runoff event (cfs)
C = discharge coefficient (0.6)
g = gravity (32.2 ft/sec^2)
L = length of weir (ft)
H = height of water over weir (ft)
θ = angle of side slopes

Q_{100} is either the peak 10-minute flow computed from the 100-year, 24-hour storm and a Type 1A distribution, or the 100-year, 1-hour flow, indicated by an approved continuous runoff model, multiplied by a factor of 1.6.

Assuming C = 0.6 and Tan θ = 3 (for 3:1 slopes), the equation becomes:

$$Q_{100} = 3.21[LH^{3/2} + 2.4\,H^{5/2}] \qquad \text{(equation 2)}$$

To find width L for the weir section, the equation is rearranged to use the computed Q_{100} and trial values of H (0.2 feet minimum):

$$L = [Q_{100}/(3.21H^{3/2})] - 2.4\,H \quad \text{or} \quad 6 \text{ feet minimum} \qquad \text{(equation 3)}$$

3.3 Infiltration Facilities ~~Stormwater Quantity and~~for Flow Control and for Treatment

3.3.1 Purpose

To provide infiltration capacity for stormwater runoff quantity and flow control.

3.3.2 Description

An infiltration BMP is typically an open basin (pond), trench, or buried perforated pipe used for distributing the stormwater runoff into the underlying soil (See Figure 3.25). Stormwater dry-wells receiving uncontaminated or properly treated stormwater can also be considered as infiltration facilities. (See Underground Injection Control Program, Chapter 173-218 WAC).

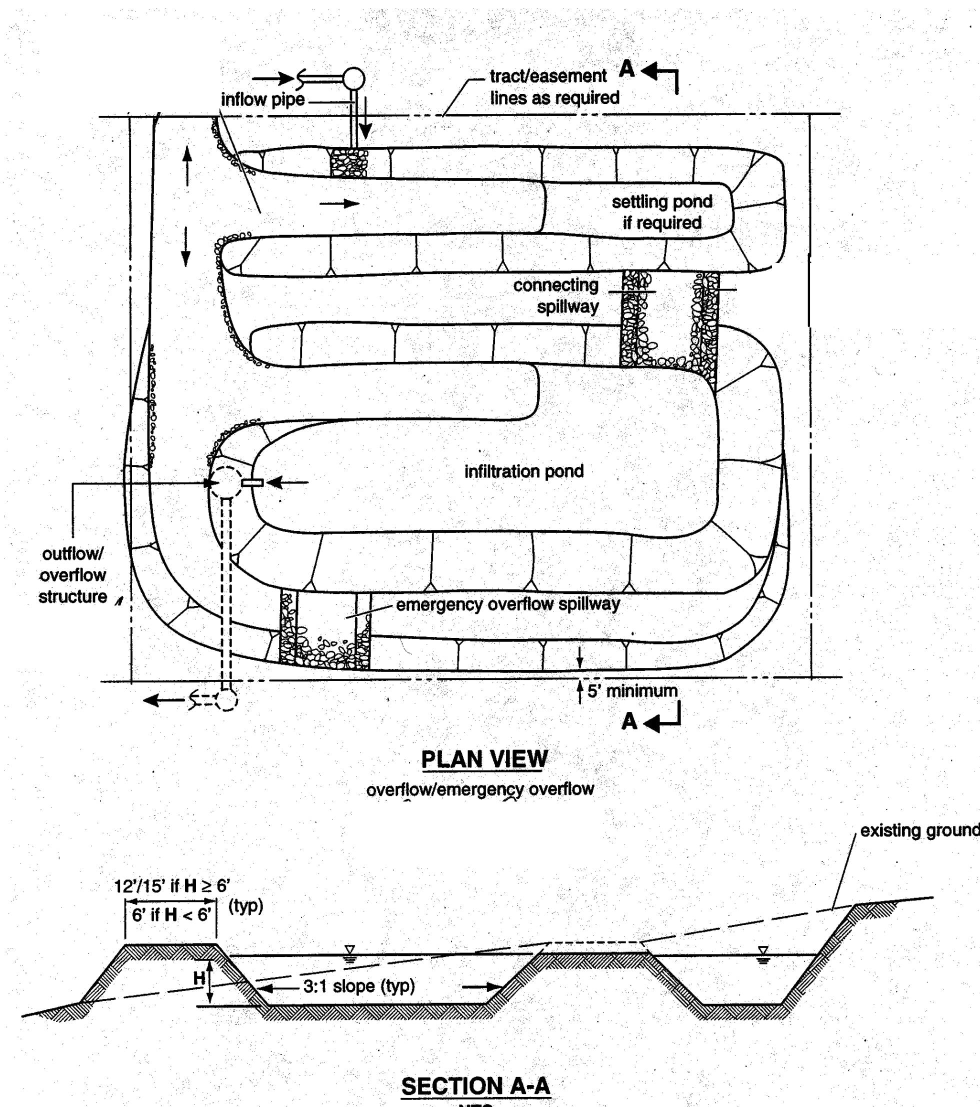
Coarser more permeable soils can be used for quantity control provided that the stormwater discharge does not cause a violation of ground water quality criteria. Typically, treatment for removal of TSS, oil, and/or soluble pollutants is necessary prior to conveyance to an infiltration BMP.

Use of the soil for treatment purposes is also an option as long as it is preceded by a pre-settling basin or a basic treatment BMP. This section highlights design criteria that are applicable to infiltration facilities serving a treatment function. ~~The hydraulic design goal should be to mimic the natural hydrologic balance between surface and ground water, as needed to protect water uses.~~

3.3.3 Applications

Infiltration facilities are used to convey stormwater runoff from new development or redevelopment to the ground and ground water after appropriate treatment. Runoff, in excess of the infiltration capacity, must be detained and released in compliance with the flow control requirement in Volume I, if flow control applies to the project.

- Ground water recharge
- Discharge of uncontaminated or properly treated stormwater to dry-wells in compliance with Ecology's UIC regulations (Chapter 173-218 WAC)
- Retrofits in limited land areas: Infiltration trenches can be considered for residential lots, commercial areas, parking lots, and open space areas.
- Flood control
- Streambank erosion control



NOTE:
Detail is a schematic representation only. Actual configuration will vary depending on specific site constraints and applicable design criteria.

Figure 3.25 Typical Infiltration Pond/Basin

3.3.4 Simplified Approach (Figure 3.25a)

The simplified approach was derived from high ground water and shallow pond sites in western Washington, and in general will produce conservative designs. The simplified approach can be used when determining the trial geometry of the infiltration facility, for small or low impact facilities, or for facilities where a more conservative design is acceptable. The simplified approach is applicable to ponds and trenches and includes the following steps:

1. Select a location:

This will be based on the ability to convey flow to the location and the expected soil conditions of the location. Conduct a preliminary surface and sub-surface characterization study (Section 3.3.5). Do a preliminary check of Site Suitability Criteria (Section 3.3.7) to initial estimate feasibility. .

2. Estimate volume of stormwater, Vdesign:

For western Washington, a continuous hydrograph should be used, requiring use of an approved continuous runoff model such as WWHM or MGSFlood for the calculations. The runoff file developed for the project site serves as input to the infiltration basin.

For infiltration basins sized simply to meet treatment requirements, the basin must successfully infiltrate 91% of the influent runoff file. The remaining 9% of the influent file can bypass the infiltration facility. However, if the bypass discharges to a surface water that is not exempt from flow control, the bypass must meet the flow control standard.

For infiltration basins sized to meet the flow control standard, the basin must infiltrate either all of the influent file, or a sufficient amount of the influent file such that any overflow/bypass meets the flow duration standard.

3. Develop trial infiltration facility geometry:

To accomplish this, an infiltration rate will need to be assumed based on previously available data, or a default infiltration rate of 0.5 inches/hour can be used. This trial facility geometry should be used to help locate the facility and for planning purposes in developing the geotechnical subsurface investigation plan.

4. Complete More Detailed Site Characterization Study and Consider Site Suitability Criteria:

Information gathered during initial geotechnical and surface investigations are necessary to know whether infiltration is feasible. The geotechnical investigation evaluates the suitability of the site for infiltration, establishes the infiltration rate for design, and evaluates slope stability, foundation capacity, and other geotechnical design information needed to design and assess constructability of the facility.

See sections 3.3.5 and 3.3.7.

5. Determine the infiltration rate as follows:

Three possible methods for estimating the long-term infiltration rate are provided in Section 3.3.6.

6. Size the facility:

Ensure that the maximum pond depth stays below the minimum required freeboard. If sizing a treatment facility, document that the 91st percentile, 24-hour runoff volume (indicated by WWHM or MGS Flood) can infiltrate through the infiltration basin surface within 48 hours. This can be calculated using a horizontal projection of the infiltration basin mid-depth dimensions and the estimated long-term infiltration rate.

7. Construct the facility:

Maintain and monitor the facility for performance

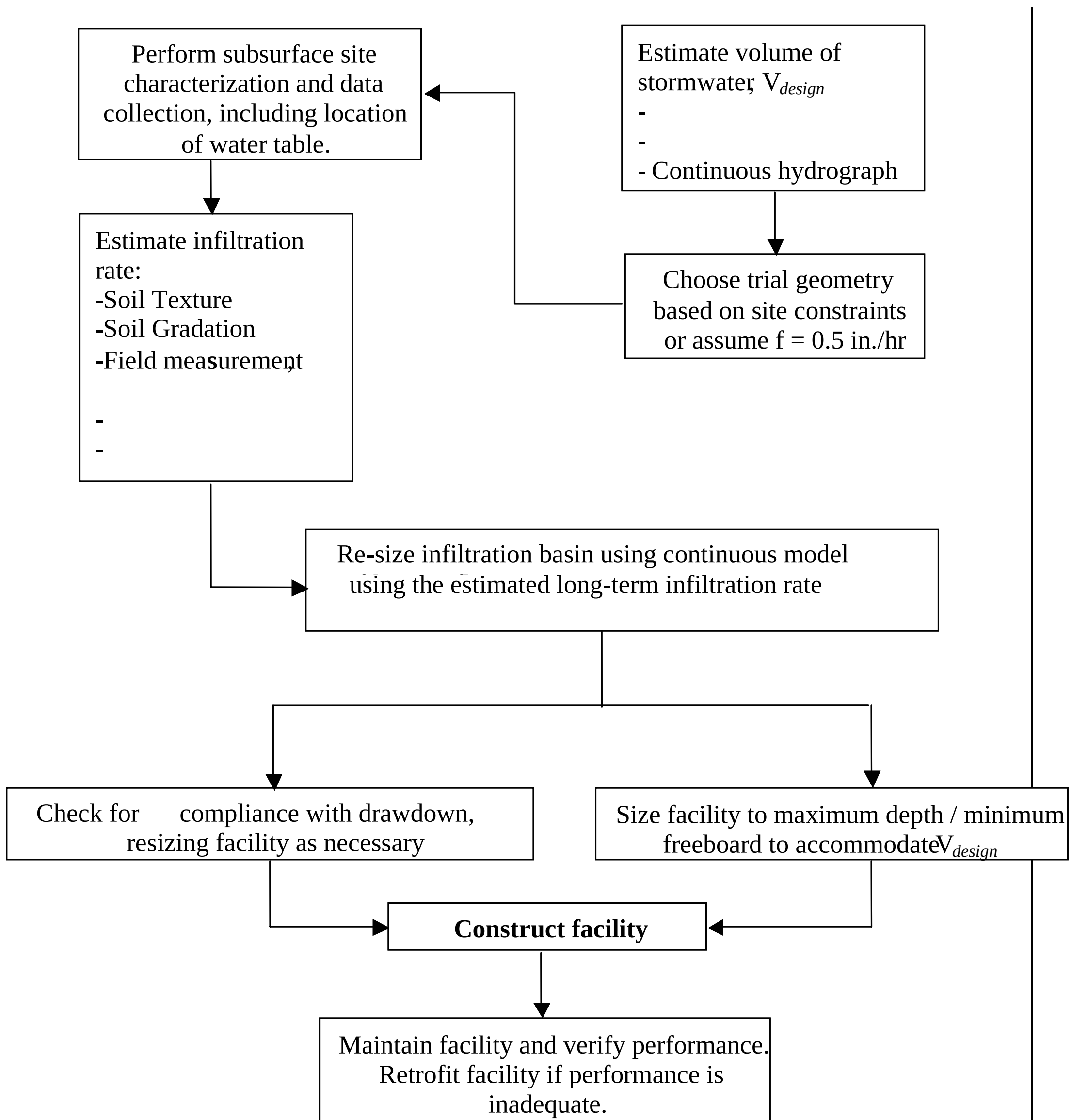


Figure 3.25a. Design steps for design of infiltration facilities – simplified approach.

3.3.45 Site Characterization Criteria

One of the first steps in siting and designing infiltration facilities is to conduct a characterization study that includes the following:

Note: Information gathered during initial geotechnical investigations can be used for the site characterization.

Surface Features Characterization:

1. Topography within 500 feet of the proposed facility.
2. Anticipated site use (street/highway, residential, commercial, high-use site).
3. Location of water supply wells within 500 feet of proposed facility.
4. Location of ground water protection areas and/or 1, 5 and 10 year time of travel zones for municipal well protection areas.
5. A description of local site geology, including soil or rock units likely to be encountered, the groundwater regime, and geologic history of the site.

Subsurface Characterization:

1. Subsurface explorations (test holes or test pits) to a depth below the base of the infiltration facility of at least 5 times the maximum design depth of ponded water proposed for the infiltration facility,
2. Continuous sampling (representative samples from each soil type and/or unit within the infiltration receptor) to a depth below the base of the infiltration facility of 2.5 times the maximum design ponded water depth, but not less than 6 feet.
   - For basins, at least one test pit or test hole per 5,000 ft^2 of basin infiltrating surface (in no case less than two per basin).
   - For trenches, at least one test pit or test hole per 50 feet of trench length (in no case less than two per trench).

Note: The depth and number of test holes or test pits, and samples should be increased, if in the judgment of a licensed engineer with geotechnical expertise (P.E.), or other licensed professional acceptable to the local jurisdiction, the conditions are highly variable and such increases are necessary to accurately estimate the performance of the infiltration system. The exploration program may also be decreased if, in the opinion of the licensed engineer or other professional, the conditions are relatively uniform and the borings/test pits omitted will not influence the design or successful operation of the facility. In high water table sites, the subsurface exploration sampling need not be conducted lower than two (2) feet below the ground water table.

3. Prepare detailed logs for each test pit or test hole and a map showing the location of the test pits or test holes. Logs must include at a minimum, depth of pit or hole, soil descriptions, depth to water, presence of stratification *(note: Logs must substantiate whether stratification does or does not exist. The licensed professional may consider additional methods of analysis to substantiate the presence of stratification that will significantly impact the design of the infiltration facility).*

Infiltration Rate Determination:

Determine the representative infiltration rate of the unsaturated vadose zone based on infiltration tests and/or grain-size distribution/texture (see next section). Determine site infiltration rates using the Pilot Infiltration Test (PIT) described in Appendix V-B, if practicable. Such site testing should be considered to verify infiltration rate estimates based on soil size distribution and textural analysis. Infiltration rates may also be estimated based on soil grain-size distributions from test pits or test hole samples (particularly where a sufficient source of water does not exist to conduct a pilot infiltration test). As a minimum, one soil grain-size analysis per soil stratum in each test hole shall be performed within 2.5 times the maximum design water depth, but not less than 6 feet.

Soil Testing:

Soil characterization for each soil unit (soils of the same texture, color, density, compaction, consolidation and permeability) encountered should include:

- Grain-size distribution (ASTM D422 or equivalent AASHTO specification)
- Textural class (USDA) (See Figure 6.1)
- Percent clay content (include type of clay, if known)
- Color/mottling
- Variations and nature of stratification

If the infiltration facility will be used to provide treatment as well as flow control, the soil characterization should also include:

- Cation exchange capacity (CEC) and organic matter content for each soil type and strata. Where distinct changes in soil properties occur, to a depth below the base of the facility of at least 2.5 times the maximum design water depth, but not less than 6 feet. Consider if soils are already contaminated, thus diminishing pollutant sorptive capacity.

- For soils with low CEC and organic content, deeper characterization of soils may be warranted (refer to Section 3.3.6 Site Suitability Criteria)

Infiltration Receptor:

Infiltration receptor (unsaturated and saturated soil receiving the stormwater) characterization should include:

1. Installation of ground water monitoring wells (at least three per infiltration facility, or three hydraulically connected surface and ground water features that will establish a three-dimensional relationship for the ground water table, unless the highest ground water level is known to be at least 50 feet below the proposed infiltration facility) to:

   - monitor the seasonal ground water levels at the site during at least one wet season, and,
   - consider the potential for both unconfined and confined aquifers, or confining units, at the site that may influence the proposed infiltration facility as well as the groundwater gradient. Other approaches to determine ground water levels at the proposed site could be considered if pre-approved by the local government jurisdiction, and,
   - determine the ambient ground water quality, if that is a concern.

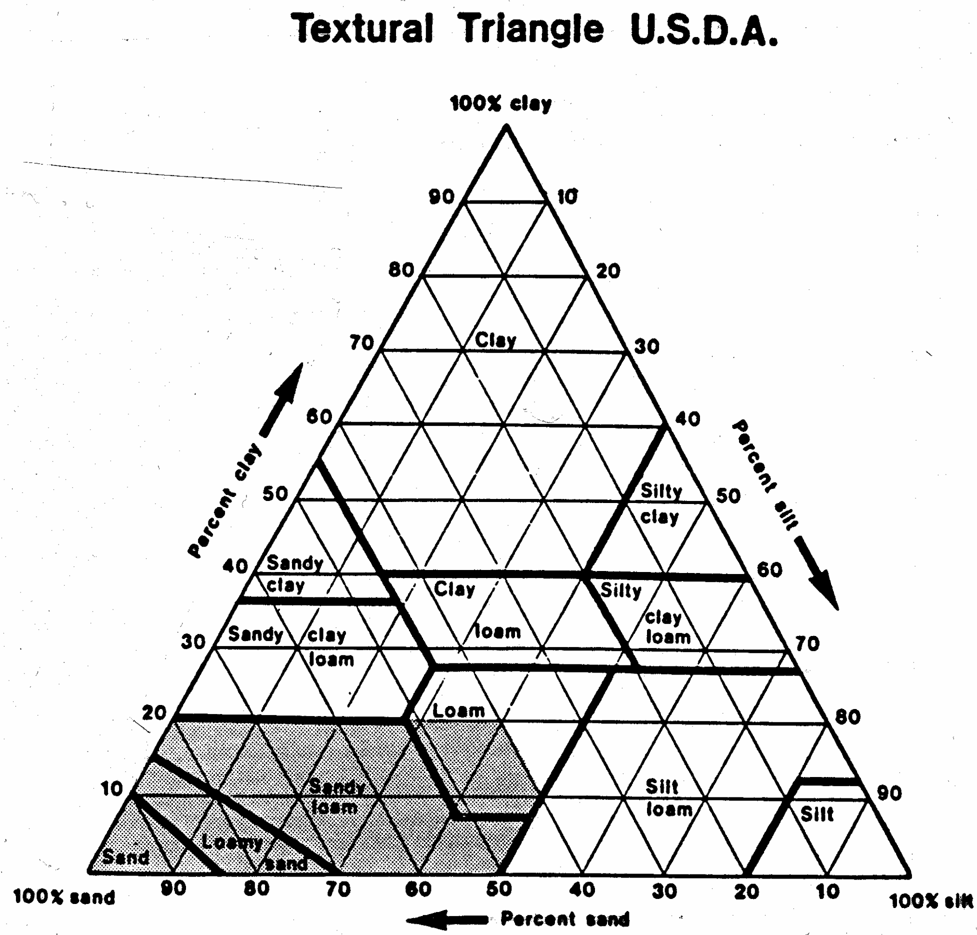
2. An estimate of the volumetric water holding capacity of the infiltration receptor soil. This is the soil layer below the infiltration facility and above the seasonal high-water mark, bedrock, hardpan, or other low permeability layer. This analysis should be conducted at a conservatively high infiltration rate based on vadose zone porosity, and the water quality runoff volume to be infiltrated. This, along with an analysis of ground water movement, will be useful in determining if there are volumetric limitations that would adversely affect drawdown.

3. Determination of:

   - Depth to ground water table and to bedrock/impermeable layers
   - Seasonal variation of ground water table based on well water levels and observed mottling
   - Existing ground water flow direction and gradient
   - Lateral extent of infiltration receptor
   - Horizontal hydraulic conductivity of the saturated zone to assess the aquifer's ability to laterally transport the infiltrated water.
   - Impact of the infiltration rate and volume at the project site on ground water mounding, flow direction, and water table; and the

discharge point or area of the infiltrating water. A ground water mounding analysis should be conducted at all sites where the depth to seasonal ground water table or low permeability stratum is less than 15 feet and the runoff to the infiltration facility is from more than one acre. *(The site professional can consider conducting an aquifer test, or slug test and the type of ground water mounding analysis necessary at the site)*

Note: A detailed soils and hydrogeologic investigation should be conducted if potential pollutant impacts to ground water are a concern, or if the applicant is proposing to infiltrate in areas underlain by till or other impermeable layers. (Suggested references: "Implementation Guidance for the Ground Water Quality Standards", Department of Ecology, publication 96-2, 1996, and, "Washington State Water Quality Guide," Natural Resources Conservation Service, W. 316 Boone Ave, Spokane WA 99201-2348).



Shaded area is applicable for design of infiltration BMPs

Figure 3.26 USDA Textural Triangle

Source: U.S. Department of Agriculture

3.3.~~5~~6 Design Infiltration Rate Determination - Guidelines and Criteria

~~The representative site infiltration rate must be determined from soil test results, the stratification identified during the site characterization, and/or in-situ field measurements.~~

Infiltration rates can be determined using either a correlation to grain size distribution from soil samples, textural analysis, or by in-situ field measurements. Short-term infiltration rates up to 2.4 in./hr represent soils that typically have sufficient treatment properties. Long-term infiltration rates are used for sizing the infiltration pond based on maximum pond level and drawdown time. Long-term infiltration rates up to 2.0 inches per hour can also be considered for treatment if SSC-4 and SSC-6 are met, as defined in Section 3.3.6.

Historically, infiltration rates have been estimated from soil grain size distribution (gradation) data using the United States Department of Agriculture (USDA) textural analysis approach. To use the USDA textural analysis approach, the grain size distribution test must be conducted in accordance with the USDA test procedure (SOIL SURVEY MANUAL, U.S. Department of Agriculture, October 1993, page 136). This manual only considers soil passing the #10 sieve (2 mm) (U.S. Standard) to determine percentages of sand, silt, and clay for use in Figure 3.26 (USDA Textural Triangle). However, many soil test laboratories use the ASTM soil size distribution test procedure (ASTM D422), which considers the full range of soil particle sizes, to develop soil size distribution curves. The ASTM soil gradation procedure must not be used with Figure 3.26 to perform USDA soil textural analyses.

Three Methods for Determining Long-term Infiltration Rates for Sizing Infiltration Facilities

For designing the infiltration facility the site professional should select one of the three methods described below that will best represent the long-term infiltration rate at the site. The long-term infiltration rate should be used for routing and sizing the basin/trench for the maximum drawdown time of 24 hours. If the pilot infiltration test (table 3.9) or hindcast approach (table 3.8) is selected corroboration with a textural based infiltration rate (table 3.7) is also desirable. Appropriate correction factors must be applied as specified. Verification testing of the completed facility is strongly encouraged. (See Site Suitability Criterion # 7-Verification Testing)

1. USDA Soil Textural Classification

Table 3.7 provides the correlation between USDA soil texture and infiltration rates for estimating infiltration rates for homogeneous soils based on gradations from soil samples and textural analysis. The USDA soil texture – infiltration rate correlation in Table 3.7 is based on the correlation developed by Rawls, et. al. (1982), but with minor changes in the infiltration rates based on WEF/ASCE (1998). The infiltration rates provided through this correlation represent short-term conservative rates for homogeneous soils. These rates not consider the effects of site variability and long-term clogging due to siltation and biomass buildup in the infiltration facility.

Table 3.7 -- Recommended Infiltration Rates based on USDA Soil Textural Classification.

	***Short-Term Infiltration Rate (in./hr)**	**Correction Factor, CF**	**Estimated Long-Term (Design) Infiltration Rate (in./hr)**
Clean sandy gravels and gravelly sands (i.e., 90% of the total soil sample is retained in the #10 sieve)	20	2	10**
Sand	8	4	2***
Loamy Sand	2	4	0.5
Sandy Loam	1	4	0.25
Loam	0.5	4	0.13

*From WEF/ASCE, 1998.
**Not recommended for treatment
*** Refer to SSC-4 and SSC-6 for treatment acceptability criteria

Based on experience with long-term full-scale infiltration pond performance, Ecology's Technical Advisory Committee (TAC) recommends that the short-term infiltration rates be reduced as shown in Table 3.7, dividing by a correction factor of 2 to 4, depending on the soil textural classification. The correction factors provided in Table 3.7 represent an average degree of long-term facility maintenance, TSS reduction through pretreatment, and site variability in the subsurface conditions. These conditions might include deposits of ancient landslide debris, buried stream channels, lateral grain size variability, and other factors that affect homogeneity).

These correction factors could be reduced, subject to the approval of the local jurisdiction, under the following conditions:

- For sites with little soil variability,
- Where there will be a high degree of long-term facility maintenance,
- Where specific, reliable pretreatment is employed to reduce TSS entering the infiltration facility

In no case shall a correction factor less than 2.0 be used.

Correction factors higher than those provided in Table 3.7 should be considered for situations where long-term maintenance will be difficult to implement, where little or no pretreatment is anticipated, or where site conditions are highly variable or uncertain. These situations require the use of best professional judgment by the site engineer and the approval of the local jurisdiction. An Operation and Maintenance plan and a financial bonding plan may be required by the local jurisdiction.

2. ASTM Gradation Testing at Full Scale Infiltration Facilities

As an alternative to Table 3.7, recent studies by Massmann and Butchart (2000) were used to develop the correlation provided in Table 3.8. These studies compare infiltration measurements from full-scale infiltration facilities to soil gradation data developed using the ASTM procedure (ASTM D422). The primary source of the data used by Massmann and Butchart was from Wiltsie (1998), who included limited infiltration studies only on Thurston County sites. However, Massmann and Butchart also included limited data from King and Clark County sites in their analysis. This table provides recommended long-term infiltration rates that have been correlated to soil gradation parameters using the ASTM soil gradation procedure.

Table 3.8 can be used to estimate long-term design infiltration rates directly from soil gradation data, subject to the approval of the local jurisdiction. As is true of Table 3.7, the long-term rates provided in Table 3.8 represent average conditions regarding site variability, the degree of long-term maintenance and pretreatment for TSS control. The long-term infiltration rates in Table 3.8 may need to be decreased if the site is highly variable, or if maintenance and influent characteristics are not well controlled. The data that forms the basis for Table 3.8 was from soils that would be classified as sands or sandy gravels. No data was available for finer soils at the time the table was developed.~~.~~ Therefore, Table 3.8 should not be used for soils with a d_{10} size (10% passing the size listed) less than 0.05 mm (U.S. Standard Sieve).

Table 3.8 -- Alternative Recommended Infiltration Rates based on ASTM Gradation Testing.

D_{10} Size from ASTM D422 Soil Gradation Test (mm)	Estimated Long-Term (Design) Infiltration Rate (in./hr)
$\geq$ 0.4	9*
0.3	6.5*
0.2	3.5*
0.1	2.0**
0.05	0.8

* Not recommended for treatment
* Refer to SSC-4 and SSC-6 for treatment acceptability criteria

However, additional data based on recent research (Massmann, et al. 2003) for these finer soils are now available and are shown in Figure 3.26a.

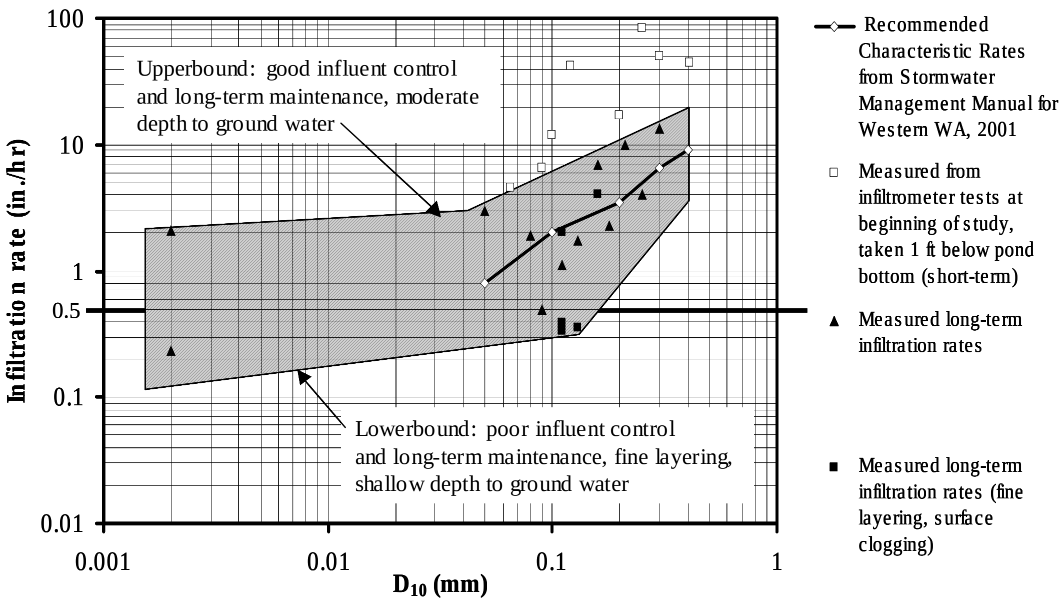


Figure 3-26a Infiltration rate as a function of the D_{10} size of the soil for ponds in Western Washington (the mean values represent low gradient conditions and relatively shallow ponds).

Figure 3.26a provides a plot of this relationship between the infiltration rate and the d_{10} of the soil, showing the empirical data upon which it is based. The figure provides an upper and lower bound range for this relationship based on the empirical data. These upper and lower bound ranges can be used to adjust the design infiltration rate to account for site-specific issues and conditions.

The long-term rates provided in Table 3.8 represent average conditions regarding site variability, the degree of long-term maintenance, and pretreatment for TSS control, and represent a moderate depth to ground water below the pond. The long-term infiltration rates in Table 3.8 may need to be decreased (i.e., toward the lower bound in Figure 3.26a) if the site is highly variable, the ground water table is shallow, there is fine layering present that would not be captured by the soil gradation testing, or maintenance and influent characteristics are not well controlled. However, if influent control is good (e.g., water entering the pond is pretreated through a biofiltration swale, pre-sedimentation pond, etc.), a good long-term maintenance plan will be implemented, and the water table is moderate in depth, then an infiltration rate toward the upper bound in the figure could be used.

The infiltration rates provided in Tables 3.7~~, and~~ 3.8, and Figure 3.26a represent rates for homogeneous soil conditions. If more than one soil unit is encountered within 6 feet of the base of the facility or 2.5 times the proposed maximum water design depth, use the lowest infiltration rate determined from each of the soil units as the representative site infiltration rate.

If soil mottling, fine silt or clay layers, which cannot be fully represented in the soil gradation tests, are present below the bottom of the infiltration pond, the infiltration rates provided in the tables will be too high and should be reduced. Based on limited full-scale infiltration data (Massmann and Butchart, 2000; Wiltsie, 1998), it appears that the presence of mottling indicates soil conditions that reduce the infiltration rate for homogeneous conditions by a factor of 3 to 4.

The rates shown in Table 3.8 and Figure 3.26a are long-term design rates. No additional correction factor is needed.

3. In-situ Infiltration Measurements

Where feasible, Ecology encourages in-situ infiltration measurements, using a procedure such as the Pilot Infiltration Test (PIT) described in Appendix V-B. Small-scale infiltration tests such as the EPA Falling Head or double ring infiltrometer test (ASTM D3385-88) are not recommended unless modified versions are determined to be acceptable by Ecology or the local jurisdiction. These small-scale infiltration tests tend to seriously overestimate infiltration rates and, based on recent TAC experience, are considered unreliable.

~~As in the previous methods, t~~The infiltration rate obtained from the PIT test shall be considered to be a short-term rate. This short-term rate must be reduced through correction factors to account for site variability and number of tests conducted, degree of long-term maintenance and influent pretreatment/control, and potential for long-term clogging due to siltation and bio-buildup.

The typical range of correction factors to account for these issues, based on TAC experience, is summarized in Table 3.9. The range of correction factors is for general guidance only. The specific correction factors used shall be determined based on the professional judgment of the licensed engineer or other site professional considering all issues which may affect the long-term infiltration rate, subject to the approval of the local jurisdictional authority.

Table 3.9 -- Correction Factors to be Used With In-Situ Infiltration Measurements to Estimate Long-Term Design Infiltration Rates.	
Issue	**Partial Correction Factor**
Site variability and number of locations tested	CF_v = 1.5 to 6
Degree of long-term maintenance to prevent siltation and bio-buildup	CF_m = 2 to 6
Degree of influent control to prevent siltation and bio-buildup	CF_i = 2 to 6

Total Correction Factor (CF) = $CF_v + CF_m + CF_i$

The following discussions are to provide assistance in determining the partial correction factors to apply in Table 3.9.

Site variability and number of locations tested - The number of locations tested must be capable of producing a picture of the subsurface conditions that fully represents the conditions throughout the facility site. The partial correction factor used for this issue depends on the level of uncertainty that adverse subsurface conditions may occur. If the range of uncertainty is low **-** for example, conditions are known to be uniform through previous exploration and site geological factors **-** one pilot infiltration test may be adequate to justify a partial correction factor at the low end of the range. If the level of uncertainty is high, a partial correction factor near the high end of the range may be appropriate. This might be the case where the site conditions are highly variable due to a deposit of ancient landslide debris, or buried stream channels. In these cases, even with many explorations and several pilot infiltration tests, the level of uncertainty may still be high. A partial correction factor near the high end of the range could be assigned where conditions have a more typical variability, but few explorations and only one pilot infiltration test is conducted. That is, the number of explorations and tests conducted do not match the degree of site variability anticipated.

Degree of long-term maintenance to prevent siltation and bio-buildup The standard of comparison here is the long-term maintenance requirements provided in Volume V, Chapter 4, and any additional requirements by local jurisdictional authorities. Full compliance with these requirements would be justification to use a partial correction factor at the low end of the range. If there is a high degree of uncertainty that long-term maintenance will be carried out consistently, or if the maintenance plan is poorly defined, a partial correction factor near the high end of the range may be justified.

Degree of influent control to prevent siltation and bio-buildup - A partial correction factor near the high end of the range may be justified under the following circumstances:

1. If the infiltration facility is located in a shady area where moss buildup or litter fall buildup from the surrounding vegetation is likely and cannot be easily controlled through long-term maintenance

2. If there is minimal pre-treatment, and the influent is likely to contain moderately high TSS levels.

If influent into the facility can be well controlled such that the planned long-term maintenance can easily control siltation and biomass buildup, then a partial correction factor near the low end of the range may be justified.

The determination of long-term design infiltration rates from in-situ infiltration test data involves a considerable amount of engineering judgment. Therefore, when reviewing or determining the final long-term design infiltration rate, the local jurisdictional authority should consider the results of both textural analyses and in-situ infiltration tests results when available.

The range of corrections advocated in Table 7.3 were originally used in regard to correcting the results of small scale infiltration tests. Ecology is interested in feedback concerning possible adjustment in the range for CF_v indicated above when applied to the results of the Pilot Inifiltration Test.

3.3.~~6~~7 Site Suitability Criteria (SSC)

This section provides criteria that must be considered for siting infiltration systems. When a site investigation reveals that any of the ~~seven~~ applicable criteria cannot be met appropriate mitigation measures must be implemented so that the infiltration facility will not pose a threat to safety, health, and the environment.

For site selection and design decisions a geotechnical and hydrogeologic report should be prepared by a qualified engineer with geotechnical and hydrogeologic experience, or a licensed geologist, hydrogeologist, or engineering geologist~~n equivalent professional acceptable to the local jurisdiction, under the seal of a registered Professional Engineer~~. The design engineer may utilize a team of certified or registered professionals in soil science, hydrogeology, geology, and other related fields.

SSC-1 Setback Criteria

Setback requirements are generally required by local regulations, uniform building code requirements, or other state regulations.

These Setback Criteria are provided as guidance.

- Stormwater infiltration facilities should be set back at least 100 feet from drinking water wells, septic tanks or drainfields, and springs used for public drinking water supplies. Infiltration facilities upgradient of drinking water supplies and within 1, 5, and 10-year time of travel zones must comply with Health Dept. requirements (Washington Wellhead Protection Program, DOH, 12/93).
- Additional setbacks must be considered if roadway deicers or herbicides are likely to be present in the influent to the infiltration system
- From building foundations; ≥ 20 feet downslope and ≥100 feet upslope
- From a Native Growth Protection Easement (NGPE); ≥20 feet
- From the top of slopes >15%; ≥ 50 feet.
- Evaluate on-site and off-site structural stability due to extended subgrade saturation and/or head loading of the permeable layer, including the potential impacts to downgradient properties, especially on hills with known side-hill seeps.

SSC-2 Ground Water Protection Areas

A site is not suitable if the infiltration facility will cause a violation of Ecology's Ground Water Quality Standards (See SSC-~~7~~9 for verification testing guidance). Local jurisdictions should be consulted for applicable pollutant removal requirements upstream of the infiltration facility, and to determine whether the site is located in an aquifer sensitive area, sole source aquifer, or a wellhead protection zone.

SSC-3 High Vehicle Traffic Areas

An infiltration BMP may be considered for runoff from areas of industrial activity and the high vehicle traffic areas described below. For such applications sufficient pollutant removal (including oil removal) must be provided upstream of the infiltration facility to ensure that ground water quality standards will not be violated and that the infiltration facility is not adversely affected.

High Vehicle Traffic Areas are:

- Commercial or industrial sites subject to an expected average daily traffic count (ADT) ≥100 vehicles/1,000 ft² gross building area (trip generation), and
- Road intersections with an ADT of ≥ 25,000 on the main roadway, or ≥ 15,000 on any intersecting roadway.

SSC-4 Soil Infiltration Rate/Drawdown Time

Infiltration Rates: Short-term and Long-term:

For infiltration facilities used for treatment purposes, the short-term soil infiltration rate should be 2.4 in./hour, or less, to a depth of 2.5 times the maximum design pond water depth, or a minimum of 6 ft. below the base of the infiltration facility. This infiltration rate is also typical for soil textures that possess sufficient physical and chemical properties for adequate treatment, particularly for soluble pollutant removal (see SSC-6). It is comparable to the textures represented by Hydrologic Groups B and C. Long-term infiltration rates up to 2.0 inches/hour can also be considered, if the infiltration receptor is not a sole-source aquifer, and in the judgment of the site professional, the treatment soil has characteristics comparable to those specified in SSC-6 to adequately control the target pollutants.

The long-term infiltration rate should also be used for maximum drawdown time and routing calculations.

Drawdown time:

~~Design to completely drain ponded runoff within 24 hours from 10-year, 24-hour recurrence frequency runoff and within 48 hours of the 100-year, 24-hour recurrence frequency runoff.~~ For infiltration facilities designed strictly for flow control purposes, there isn't a maximum drawdown time.

If sizing a treatment facility, document that the 91st percentile, 24-hour runoff volume (indicated by WWHM or MGS Flood) can infiltrate through the infiltration basin surface within 48 hours. This can be calculated using a horizontal projection of the infiltration basin mid-depth dimensions and the estimated long-term infiltration rate.

This drawdown restriction is intended to meet the following objectives:

- aerate vegetation and soil to keep the vegetation healthy
- enhance the biodegradation of pollutants and organics in the soil.

(***ASKING FOR PUBLIC COMMENT ON A DRAWDOWN TIME REQUIREMENT***: *The purpose for requiring a drawdown time is to allow oxygenation of the soil beneath the facility to help prevent possible problems associated with septic conditions in the ground. Since the pond receives stormwater runoff which would probably have*

SSC-5 Depth to Bedrock, Water Table, or Impermeable Layer

The base of all infiltration basins or trench systems shall be ≥ 5 feet above the seasonal high-water mark, bedrock (or hardpan) or other low permeability layer. A separation down to 3 feet may be considered if the ground water mounding analysis, volumetric receptor capacity, and the design of the overflow and/or bypass structures are judged by the site professional to be adequate to prevent overtopping and meet the site suitability criteria specified in this section.

SSC-6 Soil Physical and Chemical Suitability for Treatment

(Applies to infiltration facilities used as treatment facilities not to facilities used for flow control)

The soil texture and design infiltration rates should be considered along with the physical and chemical characteristics specified below to determine if the soil is adequate for removing the target pollutants. The following soil properties must be carefully considered in making such a determination;

- Cation exchange capacity (CEC) of the treatment soil must be ≥5 milliequivalents CEC/100 g dry soil (USEPA Method 9081). *Consider empirical testing of soil sorption capacity, if practicable.* Ensure that soil CEC is sufficient for expected pollutant loadings, particularly heavy metals. CEC values of >5 meq/100g are expected in loamy sands, according to Rawls, et al. Lower CEC content may be considered if it is based on a soil loading capacity determination for the target pollutants that is accepted by the local jurisdiction.

- Depth of soil used for infiltration treatment must be a minimum of 18 inches.
- Organic Content of the treatment soil (ASTM D 2974): Organic matter can increase the sorptive capacity of the soil for some pollutants. The site professional should evaluate whether the organic matter content is sufficient for control of the target pollutant(s).
- Waste fill materials should not be used as infiltration soil media nor should such media be placed over uncontrolled or non-engineered fill soils.
- Engineered soils may be used to meet the design criteria in this chapter and the performance goals in Chapters 3 and 4. Field performance evaluation(s), using acceptable protocols, would be needed to determine feasibility, and acceptability by the local jurisdiction. See also Chapter 12.

SSC-7 Seepage Analysis and Control

Determine whether there would be any adverse effects caused by seepage zones on nearby building foundations, basements, roads, parking lots or sloping sites.

SSC-~~6~~8 **Cold Climate and Impact of Roadway deicers**

- For cold climate design criteria (snowmelt/ice impacts) refer to D. Caraco and R. Claytor reference.
- Potential impact of roadway deicers on potable water wells must be considered in the siting determination. Mitigation measures must be implemented if infiltration of roadway deicers can cause a violation of ground water quality standards.

SSC ~~7~~9-Verification Testing of the Completed Facility

Verification testing of the completed full-scale infiltration facility is recommended to confirm that the design infiltration parameters are adequate. The site professional should determine the duration and frequency of the verification testing program including the monitoring program for the potentially impacted ground water. The ground water monitoring wells installed during site characterization (See Section 3.3.~~4~~5) may be used for this purpose. Long-term (more than two years) in-situ drawdown and confirmatory monitoring of the infiltration facility would be preferable (See King County reference).

3.3.8 Detailed Approach

This detailed approach was obtained from Massmann (2003). Procedures for the detailed approach are as follows:

1. Select a location:

This will be based on the ability to convey flow to the location and the expected soil conditions. The minimum setback distances must also be met. See Section 3.3.7 Site Suitability Criteria and setback distances.

2. Estimate volume of stormwater, V_{design}:

A continuous hydrograph should be used, requiring a model such as the WWHM or MGSFlood to perform the calculations.

3. Develop a trial infiltration facility geometry based on length, width, and depth:

To accomplish this, either assume an infiltration rate based on previously available data, or use a default infiltration rate of 0.5 inches/hour. This trial geometry should be used to help locate the facility, and for planning purposes in developing the geotechnical subsurface investigation plan.

4. Conduct a geotechnical investigation:

A geotechnical investigation must be conducted to evaluate the site's suitability for infiltration, to establish the infiltration rate for design, and to evaluate slope stability, foundation capacity, and other geotechnical design information needed to design and assess constructability of the facility. Geotechnical investigation requirements are provided below.

The depth, number of test holes or test pits, and sampling described below should be increased if a licensed engineer with geotechnical expertise (P.E.), or a licensed geologist or hydrogeologist judges that conditions are highly variable and make it necessary to increase the depth or the number of explorations to accurately estimate the infiltration system's performance. The exploration program described below may be decreased if the licensed professional judges that conditions are relatively uniform, or design parameters are known to be conservative based on site specific data or experience, and the borings/test pits omitted will not influence the design or successful operation of the facility.

- For infiltration basins (ponds), at least one test pit or test hole per 5,000 ft^2 of basin infiltrating surface.
- For infiltration trenches, at least one test pit or test hole per 100 feet of trench length.

- Subsurface explorations (test holes or test pits) to a depth below the base of the infiltration facility of at least 5 times the maximum design depth of water proposed for the infiltration facility, or at least 2 feet into the saturated zone.
- Continuous sampling to a depth below the base of the infiltration facility of 2.5 times the maximum design depth of water proposed for the infiltration facility, or at least 2 feet into the saturated zone, but not less than 6 feet. Samples obtained must be adequate for the purpose of soil gradation/classification testing.
- Ground water monitoring wells installed to locate the ground water table and establish its gradient, direction of flow, and seasonal variations, considering both confined and unconfined aquifers. (Monitoring through at least one wet season is required, unless site historical data regarding ground water levels is available.) In general, a minimum of three wells per infiltration facility, or three hydraulically connected surface or ground water features, are needed to determine the direction of flow and gradient. If gradient and flow direction are not required, and there is low risk of down-gradient impacts, one monitoring well is sufficient. Alternative means of establishing the ground water levels may be considered. If the ground water in the area is known to be greater than 50 feet below the proposed facility, detailed investigation of the ground water regime is not necessary.
- Laboratory testing as necessary to establish the soil gradation characteristics, and other properties as necessary, to complete the infiltration facility design. At a minimum, one-grain size analysis per soil stratum in each test hole must be conducted within 2.5 times the maximum design water depth, but not less than 6 feet. When assessing the hydraulic conductivity characteristics of the site, soil layers at greater depths must be considered if the licensed professional conducting the investigation determines that deeper layers will influence the rate of infiltration for the facility, requiring soil gradation/classification testing for layers deeper than indicated above.

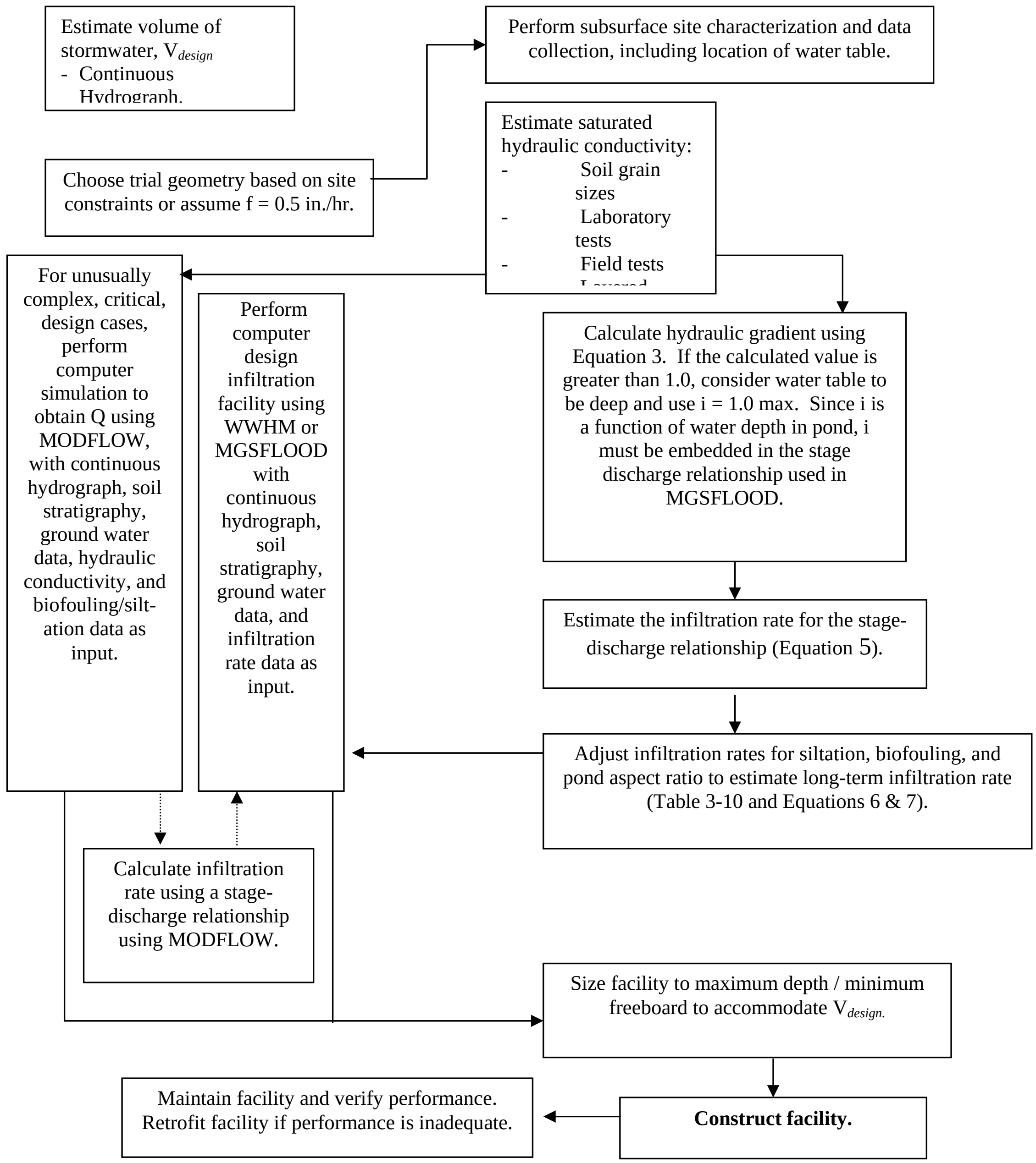


Figure 3-26b. Engineering design steps for final design of infiltration facilities using the continuous hydrograph method.

5. From the geotechnical investigation, determine the following, as applicable:

- The stratification of the soil/rock below the infiltration facility, including the soil gradation (and plasticity, if any) characteristics of each stratum.
- The depth to the ground water table and to any bedrock/impermeable layers.
- Seasonal variation of the ground water table.
- The existing ground water flow direction and gradient.
- The hydraulic conductivity or the infiltration rate for the soil/rock at the infiltration facility.
- The porosity of the soil below the infiltration facility but above the water table.
- The lateral extent of the infiltration receptor.
- Impact of the infiltration rate and volume on flow direction and water table at the project site, and the potential discharge point or area of the infiltrating water.

6. Determine the saturated hydraulic conductivity as follows:

For each defined layer below the pond to a depth below the pond bottom of 2.5 times the maximum depth of water in the pond, but not less than 6 feet, estimate the saturated hydraulic conductivity in cm/sec using the following relationship (see Massmann 2003, and Massmann et al., 2003)

$$\log_{10}(K_{sat}) = -1.57 + 1.90 D_{10} + 0.015 D_{60} - 0.013 D_{90} - 2.08 f_{fines} \quad (1)$$

Where, D_{10}, D_{60} and D_{90} are the grain sizes in mm for which 10 percent, 60 percent and 90 percent of the sample is more fine and f_{fines} is the fraction of the soil (by weight) that passes the number-200 sieve (K_{sat} is in cm/s).

If the licensed professional conducting the investigation determines that deeper layers will influence the rate of infiltration for the facility, soil layers at greater depths must be considered when assessing the site's hydraulic conductivity characteristics. Massmann (2003) indicates that where the water table is deep, soil or rock strata up to 100 feet below an infiltration facility can influence the rate of infiltration. Note that only the layers near and above the water table or low permeability zone (e.g., a clay, dense glacial till, or rock layer) need to be considered, as the layers below the ground water table or low permeability zone do not significantly influence the rate of infiltration. Also note that this equation for estimating hydraulic conductivity assumes minimal compaction consistent with the use of tracked (i.e., low to moderate ground pressure) excavation equipment. If the soil layer being characterized has been exposed to heavy compaction, or is heavily over consolidated due to its geologic history (e.g., overridden by continental glaciers), the hydraulic conductivity for the layer could be approximately an order of magnitude less than what would be estimated based on grain size characteristics alone (Pitt, 2003). In such cases, compaction effects must be taken into account when estimating hydraulic conductivity. For clean, uniformly graded sands and gravels, the reduction in K_{sat} due to compaction will be much less than an order of magnitude. For well-graded sands and gravels with moderate to high silt content, the reduction in K_{sat} will be close to an order of magnitude. For soils that contain clay, the reduction in K_{sat} could be greater than an order of magnitude.

For critical designs, the in-situ saturated conductivity of a specific layer can be obtained through field tests such as the packer permeability test (above or below the water table), the piezocone (below the water table), an air conductivity test (above the water table), or through the use of a pilot infiltration test (PIT) as described in Appendix V-B. Note that these field tests generally provide a hydraulic conductivity combined with a hydraulic gradient (i.e., Equation 5). In some of these tests, the hydraulic gradient may be close to 1.0; therefore, in effect, the magnitude of the test result is the same as the hydraulic conductivity. In other cases, the hydraulic gradient may be close to the gradient that is likely to occur in the full-scale infiltration facility. This issue will need to be evaluated on a case-by-case basis when interpreting the results of field tests. It is important to recognize that the gradient in the test may not be the same as the gradient likely to occur in the full-scale infiltration facility in the long-term (i.e., when ground water mounding is fully developed).

Once the saturated hydraulic conductivity for each layer has been identified, determine the effective average saturated hydraulic conductivity below the pond. Hydraulic conductivity estimates from different layers can be combined using the harmonic mean:

$$K_{equiv} = \frac{d}{\sum \frac{d_i}{K_i}} \qquad (2)$$

Where, d is the total depth of the soil column, d_i is the thickness of layer "i" in the soil column, and K_i is the saturated hydraulic conductivity of layer "i" in the soil column. The depth of the soil column, d, typically would include all layers between the pond bottom and the water table.

However, for sites with very deep water tables (>100 feet) where ground water mounding to the base of the pond is not likely to occur, it is recommended that the total depth of the soil column in Equation 2 be limited to approximately 20 times the depth of pond. This is to ensure that the most important and relevant layers are included in the hydraulic conductivity calculations. Deep layers that are not likely to affect the infiltration rate near the pond bottom should not be included in Equation 2. Equation 2 may over-estimate the effective hydraulic conductivity value at sites with low conductivity layers immediately beneath the infiltration pond. For sites where the lowest conductivity layer is within five feet of the base of the pond, it is suggested that this lowest hydraulic conductivity value be used as the equivalent hydraulic conductivity rather than the value from Equation 2. The harmonic mean given by Equation 2 is the appropriate effective hydraulic conductivity for flow that is perpendicular to stratigraphic layers, and will produce conservative results when flow has a significant horizontal component such as could occur due to ground water mounding.

7. Calculate the hydraulic gradient as follows:

The steady state hydraulic gradient is calculated as follows:

$$\text{gradient} = i \approx \frac{D_{wt} + D_{pond}}{138.62(K^{0.1})} CF_{size} \tag{3}$$

Where, D_{wt} is the depth from the base of the infiltration facility to the water table in feet, K is the saturated hydraulic conductivity in feet/day, D_{pond} is the depth of water in the facility in feet/day (see Massmann et al., 2003, for the development of this equation), and CF_{size}, is the correction for pond size. The correction factor was developed for ponds with bottom areas between 0.6 and 6 acres in size. For small ponds (ponds with area equal to 2/3 acre), the correction factor is equal to 1.0. For large ponds (ponds with area equal to 6 acres), the correction factor is 0.2, as shown in Equation 4.

$$CF_{size} = 0.73(A_{pond})^{-0.76} \tag{4}$$

Where, A_{pond} is the area of pond bottom in acres. This equation generally will result in a calculated gradient of less than 1.0 for moderate to shallow ground water depths (or to a low permeability layer) below the facility, and conservatively accounts for the development of a ground water mound. A more detailed ground water mounding analysis using a program such as MODFLOW will usually result in a gradient that is equal to or greater than the gradient calculated using Equation 3. If the calculated gradient is greater than 1.0, the water table is considered to be deep, and a maximum gradient of 1.0 must be used. Typically, a depth to ground water of 100 feet or more is required to obtain a gradient of 1.0 or more using this equation. Since the gradient is a function of depth of water in the facility, the gradient will vary as the pond fills during the season. The gradient could be calculated as part of the stage-discharge calculation used in the continuous runoff models. As of the date of this update, neither the WWHM or MGSFlood have that capability. However, updates to those models may soon incorporate the capability. Until that time, a steady-state hydraulic gradient that corresponds with a ponded depth of ¼ of the maximum ponded depth – as measured from the basin floor to the overflow.

8. Calculate the infiltration rate using Darcy's law as follows:

$$f = K\left(\frac{dh}{dz}\right) = Ki \qquad (5)$$

Where, f is the specific discharge or infiltration rate of water through a unit cross-section of the infiltration facility (L/t), K is the hydraulic conductivity (L/t), dh/dz is the hydraulic gradient (L/L), and "i" is the gradient.

9. Adjust infiltration rate or infiltration stage-discharge relationship obtained in Steps 8 and 9:

This is done to account for reductions in the rate resulting from long-term siltation and biofouling, taking into consideration the degree of long-term maintenance and performance monitoring anticipated, the degree of influent control (e.g., pre-settling ponds biofiltration swales, etc.), and the potential for siltation, litterfall, moss buildup, etc. based on the surrounding environment. It should be assumed that an average to high degree of maintenance will be performed on these facilities. A low degree of maintenance should be considered only when there is no other option (e.g., access problems). The infiltration rate estimated in Step 8 and 9 is multiplied by the reduction factors summarized in Table 3-10.

Table 3-10. Infiltration rate reduction factors to account for biofouling and siltation effects for ponds (Massmann, 2003).

Potential for Biofouling	Degree of Long-Term Maintenance/Performance Monitoring	Infiltration Rate Reduction Factor, $CF_{silt/bio}$
Low	Average to High	0.9
Low	Low	0.6
High	Average to High	0.5
High	Low	0.2

The values in this table assume that final excavation of the facility to the finished grade is deferred until all disturbed areas in the upgradient drainage area have been stabilized or protected (e.g., construction runoff is not allowed into the facility after final excavation of the facility). Ponds located in shady areas where moss and litterfall from adjacent vegetation can build up on the pond bottom and sides, the upgradient drainage area will remain in a disturbed condition long-term, and no pretreatment (e.g., pre-settling ponds, biofiltration swales, etc.) is provided, are one example of a situation with a high potential for biofouling. A low degree of long-term maintenance includes, for example, situations where access to the facility for maintenance is very difficult or limited, or where there is minimal control of the party responsible for enforcing the required maintenance. A low degree of maintenance should be considered only when there is no other option.

Also adjust this infiltration rate for the effect of pond aspect ratio by multiplying the infiltration rate determined in Step 9 (Equation 6) by the aspect ratio correction factor F_{aspect} as shown in the following equation:

$$CF_{aspect} = 0.02A_r + 0.98 \qquad (6)$$

Where, A_r is the aspect ratio for the pond (length/width). In no case shall CF_{aspect} be greater than 1.4.

The final infiltration rate will therefore be as follows:

$$f = K \bullet i \bullet CF_{aspect} \bullet CF_{silt/bio} \qquad (7)$$

The rates calculated based on Equations 5 and 7 are long-term design rates. No additional reduction factor or factor of safety is needed.

10. Size the facility:

Size the facility to ensure that the desirable pond depth is three feet, with one-foot minimum required freeboard. The maximum allowable pond depth is six feet.

Where the infiltration facility is being used to meet treatment requirements, check that the 91st percentile, 24-hour runoff volume (indicated by WWHM or MGS Flood) can infiltrate through the infiltration basin surface within 48 hours. This can be calculated using a horizontal projection of the infiltration basin mid-depth dimensions and the estimated long-term infiltration rate.

check to make sure that the basin can drain its maximum ponded water depth within 24 hours..

11. **Construct the facility:**

Maintain and monitor the facility for performance in accordance with section 3.3.8.

3.3.~~7~~8 General Design, Maintenance, and Construction Criteria for Infiltration Facilities

This section covers design, construction and maintenance criteria that apply to infiltration basins and trenches.

Design Criteria – Sizing Facilities

The size of the infiltration facility can be determined by routing the influent runoff file generated by the continuous runoff model ~~appropriate stormwater runoff~~ through it. -To prevent the onset of anaerobic conditions, ~~the~~an infiltration facility designed for treatment purposes must be designed to drain the 91st percentile, 24-hour runoff volume ~~completely~~ within 24 hours (see explanation under simplified or detailed design procedures. ~~after the flow to it has stopped~~.

*(**ASKING FOR PUBLIC COMMENT ON A DRAWDOWN TIME REQUIREMENT**: The purpose for requiring a drawdown time is to allow oxygenation of the soil beneath the facility to help prevent possible problems associated with septic conditions in the ground. Since the pond receives stormwater runoff which would probably have a relatively low biological oxygen demands, how valid is the septicity concern ? What is a reasonable drawdown time?).*

In general, an infiltration facility would have 2 discharge modes. The primary mode of discharge from an infiltration facility is infiltration into the ground. However, when the infiltration capacity of the facility is reached, additional runoff to the facility will cause the facility to overflow. Overflows from an infiltration facility must comply with the Minimum Requirement #7 for flow control in Volume I. Infiltration facilities used for runoff treatment must not overflow more than 9% of the influent runoff file.

In order to determine compliance with the flow control requirements, the Western Washington Hydrology Model (WWHM), or an appropriately calibrated continuous simulation model based on HSPF, must be used.

When using WWHM for simulating flow through an infiltrating facility, the facility is represented by using the Pond Icon and entering the pre-determined infiltration rates. Below are the procedures for sizing a pond (A)- to completely infiltrate 100% of runoff; (B)- to treat 91% of runoff to meet the water quality treatment requirements, and (C)- to partially infiltrate runoff to meet flow duration standard.

~~a spreadsheet may be used to calculate infiltration rates as a function of the infiltrating surface area of the facility. A stage-area-storage-discharge table must be generated that shows the facility's storage and infiltration as a function of the stage. The table must also show the facility's overflow discharge as a function of stage. This table can be imported to the WWHM as an electronic text file, or, the table can be typed directly into the WWHM. WWHM can route the historic runoff hydrograph for the developed condition through the infiltration pond and determine if the overflow from the facility complies with flow control requirement #7.~~

(A) For 100% infiltration

(1)- Input dimensions of your infiltration pond,

(2)- Input infiltration rate and safety (rate reduction) factor,

(3)- Input a riser height and diameter (any flow through the riser indicates that you have less than 100% infiltration and must increase your infiltration pond dimensions).

(4)- Run only HSPF for Developed Mitigated Scenario (if that is where you put the infiltration pond). Don't need to run duration.

(5)- Go back to your infiltration pond and look at the Percentage Infiltrated at the bottom right. If less than 100% infiltrated, increase pond dimension until you get 100%.

(B) For 91% infiltration (Water Quality Treatment volume)

The procedure is the same as above, except that your target is 91%.

Infiltration facilities for treatment can be located upstream or downstream of detention and can be off-line or on-line.

On-line treatment facilities placed ***upstream or downstream*** of a detention facility must be sized to infiltrate 91% of the runoff file volume directed to it.

Off-line treatment facilities placed ***upstream*** of a detention facility must have a flow splitter designed to send all flows at or below the 15-minute water quality flow rate, as predicted by WWHM, to the treatment facility. Within the WWHM, the flow splitter icon is placed ahead of the pond icon which represents the infiltration basin. The treatment facility must be sized to infiltrate all the runoff sent to it (no overflows from the treatment facility are allowed).

Off-line treatment facilities placed ***downstream*** of a detention facility must have a flow splitter designed to send all flows at or below the 2-year flow frequency from the detention pond, as predicted by WWHM, to the treatment facility. Within the WWHM, the flow splitter icon is placed ahead of the pond icon which represents the infiltration basin. The treatment facility must be sized to infiltrate all the runoff sent to it (no overflows from the treatment facility are allowed).

See Chapter 4 for flow splitter design details.

(C) To meet flow duration standard with infiltration ponds

This design will allow something less than 100% infiltration as long as any overflows will meet the flow duration standard. You would need a discharge structure with orifices and risers similar to a detention facility except that, in addition, you also have infiltration occurring from the pond.

Additional Design Criteria

- Slope of the base of the infiltration facility should be <3 percent.
- Spillways/Overflow structures- A nonerodible outlet or spillway with a firmly established elevation must be constructed to discharge overflow. Ponding depth, drawdown time, and storage volume are calculated from that reference point. Overflow Structure-Refer to Chapter 2 for design details

Construction Criteria

- Excavate infiltration trenches and basins to final grade only after construction has been completed and all upgradient soil has been stabilized. Initial basin excavation should be conducted to within 1-foot of the final elevation of the basin floor. Any accumulation of silt in the infiltration facility must be removed before putting it in service. After construction is completed, prevent sediment from entering the infiltration facility by first conveying the runoff water through an appropriate pretreatment system such as a pre-settling basin, wet pond, or sand filter.
- Infiltration facilities should generally not be used as temporary sediment traps during construction. If an infiltration facility is to be used as a sediment trap, it must not be excavated to final grade until after the upgradient drainage area has been stabilized.
- Traffic Control - Relatively light-tracked equipment is recommended for this operation to avoid compaction of the basin floor. The use of draglines and trackhoes should be considered for constructing infiltration basins. The infiltration area should be flagged or marked to keep heavy equipment away.

Maintenance Criteria

Provision should be made for regular and perpetual maintenance of the infiltration basin/trench, with adequate access. Maintenance should be conducted when water remains in the basin or trench for more than 24 hours. An Operation and Maintenance Plan, approved by the local jurisdiction, should ensure maintaining the desired infiltration rate.

Debris/sediment accumulation**-** Removal of accumulated debris/sediment in the basin/trench should be conducted every 6 months or as needed to prevent clogging, or when water remains in the pond for greater than 24 hours at or less than design storm conditions.

Seepage Analysis and Control **-** Determine whether there would be any adverse effects caused by seepage zones on nearby building foundations, basements, roads, parking lots or sloping sites.

For more detailed information on maintenance, see Volume V, Section 4.6 – Maintenance Standards for Drainage Facilities.

Verification of Performance

During the first 1**-**2 years of operation verification testing (specified in SSC**-**~~7~~9) is strongly recommended, along with a maintenance program that results in achieving expected performance levels. Operating and maintaining ground water monitoring wells (specified in Section 3.3.~~6~~7 **-** Site Suitability Criteria) is also strongly encouraged.

The next two subsections on infiltration basins and infiltration trenches will be amended to incorporate similar guidance that is currently provided in Volume V, Chapter 7, Section 7.4. Chapter 7 of Volume V will reference this Chapter rather than repeat the same information.